STANDARDS DEVELOPMENT BRANCH OMOE
36936000004959

Regulating Ozone-Depleting Substances in Ontario:

Solvents

A Background Report

Program Development Branch
Ministry of Environment and Energy

March, 1994

TD
196
.S54
R44
1994
MOE

Copyright Provisions and Restrictions on Copying:

This Ontario Ministry of the Environment work is protected by Crown copyright (unless otherwise indicated), which is held by the Queen's Printer for Ontario. It may be reproduced for non-commercial purposes if credit is given and Crown copyright is acknowledged.

It may not be reproduced, in all or in part, part, for any commercial purpose except under a licence from the Queen's Printer for Ontario.

For information on reproducing Government of Ontario works, please contact Service Ontario Publications at copyright@ontario.ca

TD
196
.S54
R44
1994

Regulating ozone-depleting substances in Ontario : solvents : a background report.

72992

Regulating Ozone-Depleting Substances in Ontario:

Solvents

A Background Report

Program Development Branch
Ministry of Environment and Energy

March, 1994

TABLE OF CONTENTS

Executive Summary 1

1.0 Background: 2

2.0 The Threat: 10

2.1 The Environmental Case Against Ozone-Depleting Substances (ODS) 10

2.2 Effects of Ozone-Depletion on Life and Human Health 11

3.0 Solvents Uses and Alternatives: 12

3.1 Alternative Cleaning Chemicals and Technologies . 13

3.2 Substitutes for Carbon Tetrachloride 16

3.3 Alternatives for Adhesives, Dry-Cleaning, Coatings and Inks, and Aerosols 17

4.0 Economic Implications of Solvent Uses and Technologies . 19

4.1 Market Structure and Uses 19

5.0 Regulatory Activity in Other Jurisdictions: 26

5.1 International Agreements to Phase-out CFCs 27

5.2 Regulatory Activity in the United States 28

5.3 Regulatory Activity of the Government of Canada . . 30

5.4 Regulatory Activities in Other Provinces 33

5.5 Potential Responses to Regulatory Requirements . . 38

6.0 References 39

Appendix A: Solvent Uses and Alternatives - Comparison Tables:

A.1 Methyl Chloroform, MCF 41

A.2 Trichlorotrifluoroethane, CFC-113 61

A.3 Carbon Tetrachloride, CTC 77

A.4 Hydrochlorofluorocarbons, HCFCs 78

Executive Summary

Elimination of ozone-depleting substances (ODS) has recently received the attention for immediate action by the international community. One hundred and twenty five countries, including Canada, have signed the Montreal Protocol and subsequent agreements for phasing-out the production of ODS, including chlorofluorocarbons (CFCs), methyl chloroform (MCF) and carbon tetrachloride (CTC) by 1996, and 99.5% of hydrochlorofluorocarbons (HCFCs) by 2020. The latter are considered as transitional substances and are also destined for elimination.

Solvents containing CFCs, CTC and MCF are widely used by industrial sectors such as: electronics - 68%, metal-cleaning - 20%, general cleaning - 9% and dry-cleaning - 3%.

Major users in the electronics industry, such as Northern Telecom, 3M, XEROX and IBM in Canada, and AT&T in the U.S. have changed their procedures to non-solvent technologies. Others, such as Ontario Hydro are phasing-out the use of CFC-113 from their cleaning operations prior to 1996.

There is little audit information on small users of ODS solvents, the quantities used and applications. For this reason, communicating the international phase-out dates to small businesses is a major challenge. However, as supplies of ODS-solvents are reduced and prices are increased, the small business sector will seek alternative solvents, and may also invest in new equipment.

The Canadian federal government, in-line with the Montreal Protocol's requirements, is currently developing a new regulation that requires:

- 75% and 100% reduction in the production, import and export of CFCs in 1994 and 1996 respectively;
- 50% and 100% reduction in MCF in 1994 and 1996 respectively;
- 85% and 100% reduction in CTC in 1995 and 1996 respectively.

This report provides background information on solvent uses and alternatives, brief preliminary economic implications of their uses, and a summary of the regulatory activities in other jurisdictions.

Disclaimer

The views and ideas expressed in this report do not necessarily reflect the views and policies of the Ministry of Environment and Energy, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

1.0 Background:

Chlorofluorocarbons (CFCs), organic compounds made up of chlorine, fluorine and carbon atoms, were first developed and introduced in the 1930s as a result of research for safe and efficient refrigerants to replace ammonia. They are mainly non-toxic, non-flammable and chemically-stable. Today, they are used as solvents in degreasers and cleaners in: parts cleaning, dry-cleaning, chemical processes, electronics, paint-stripping, aerosol formulations, adhesives, flexible foam, pharmaceuticals, textiles, inks, and other miscellaneous applications.

For example, CFCs were introduced in 1950s for use as blowing agents in plastic and foam production. Methyl chloroform (**MCF**), (1,1,1-trichloroethane) was also introduced for metal and electronic circuits cleaning. In 1960s, in view of their various desirable properties, their use expanded rapidly into such areas as propellants, degreasers and as solvents.

Other commonly used solvents have also been identified as ozone-depleting, in particular, **CFC-113**, (trichlorotrifluoroethane, chlorofluorocarbon-113) and carbon tetrachloride (**CTC**). The latter is still used in Eastern Europe for dry-cleaning.

In the late 1980's, as the dangers of CFCs to the ozone layer in the stratosphere became more apparent, Allied Signal developed a group of substances (hydrochlorofluorocarbons (**HCFCs**), closely related to CFCs but are more reactive and hence more prone to natural destruction before reaching the upper atmosphere. They are considered as transitional chemicals since they are a step between ozone-depleting substances (ODS) and non-ODS substitutes.

Solvents are liquids (often organic chemicals) which are volatile, and which can dissolve certain types of substances.

CFC-113 , **MCF** and **CTC**, are widely used as solvents because they dissolve a wide variety of substances, are noncorrosive, volatile and, with the exception of CTC, have low-toxicity to humans.

CFC-113 is used as a cleaning solvent for circuit boards, specialty metals, plastics, polyvinyls and human implants. It is also used as a drying agent for general "spot free" cleaning.

MCF is a widely used solvent for cleaning metals, electronics and precision parts and as a drying agent in adhesives, aerosols, coatings (paints) and inks. MCF is also used in textile manufacturing and for dry-cleaning leather and suede garments.

CTC is no longer used in dry-cleaning in Canada because it is a health risk. It is now used as a feedstock for the manufacture of CFC-11 & 12 although these chemicals are no longer made in Canada. Small amounts of CTC continue to be used in solvent applications.

Unfortunately, because CFC-113, MCF and CTC are stratospheric ozone-depleting substances (ODS), therefore, they are the target of regulatory restrictions and ultimate phase-out of production and consumption in various jurisdictions, including Canada. The relative importance of these substances as ozone-depleters is measured by their ozone-depleting potential (**ODP**). This measure compares the propensity for the chlorine (or bromine) molecules in each ODS chemical to attack and break down ozone molecules against that of CFC-11. For example, CTC has an ODP of 1.1, CFC-113 has an ODP of 0.8 and methyl chloroform registers only 0.12.

HCFCs, are also ODS but less so compared with CFCs. These compounds can be used in many of the same uses as CFCs, including as a solvent. HCFCs have ODP ranging from 0.02 to 0.11 are also targeted for regulatory action by the Montreal Protocol.

Many governments around the world acknowledge the threats posed by stratospheric ozone-depletion. There is wide agreement that the production, use and release of ODS should be phased out.

This paper provides a background account on ODS solvents uses and alternatives, including a summary of the economic implications of the implementation of the Montreal Protocol. Regulatory activities in other jurisdictions are also presented.

In Table 1, the use and alternatives to some of these substances or substance groups are described.

In addition, Figures 1-5 provide summaries of the uses of CFCs and MCF in Canada: Figures 1 and 2 present comparative data on the use of CFC in Canada for 1989-1992; Figure 3 illustrates a breakdown of the uses of CFC by solvent users in 1989; Figure 4 shows a distribution of miscellaneous uses of CFCs in 1989; and Figure 5 describes MCF use by various industrial sectors in 1989.

Table 1: Description of ODS solvents, their uses, and potential substitutes.

Ozone Depleting Substance and ODP	Synonym	Uses	Replacements
CFC-113 ODP = 0.80	Chloro trifluoro-methane $C_2F_3Cl_3$	Cleaning solvent for: electronic circuit boards with military specifications, pace-makers and other implants to reduce body tissue rejection, specialty metals easily damaged by other solvents, or when a drying agent is needed for spot-free cleaning.	Alternative cleaning methods using alcohol; changes in electronic residue-free technology to eliminate the need for solvents.
HCFCs examples: **HCFC-123, ODP = 0.02** **HCFC-141b, ODP = 0.10**	More than 34 varieties available	Transitional substitutes for other ozone-depleting solvents, either pure or in blends.	There may be considerable market adjustment as HCFCs themselves are phased-out.
Methyl chloroform ODP = 0.1	1,1,1 trichloro-ethane CH_3CCl_3	All purpose solvent for vapour degreasing, cold cleaning of fabricated metal parts, use as a solvent in adhesive and aerosol formulations, for the production of certain coatings and inks, in textile applications, and for dry-cleaning leather and suede garments.	Other chlorinated solvents such as perchloroethylene and trichloro-ethylene. AT&T is using non-toxic n-butyl butyrate for micro-circuit etching. Northern Telecom eliminated use of solvents.
Carbon tetra-chloride ODP = 1.1	tetrachloro-methane perchloro-methane CCl_4	Was used as feedstock for CFC-11 and CFC-12. Toxicity has limited its use as a solvent.	Other solvents.

• Ozone Depleting Potential represents the amount of ozone destroyed by emission of a gas over its entire atmospheric lifetime relative to that due to emission of the same mass of CFC-11 (trichlorofluoromethane, lifetime 55 years) which is given an ODP value of 1.0. i.e ODP = Global change in ozone due to X / Global change in ozone due to CFC-11.

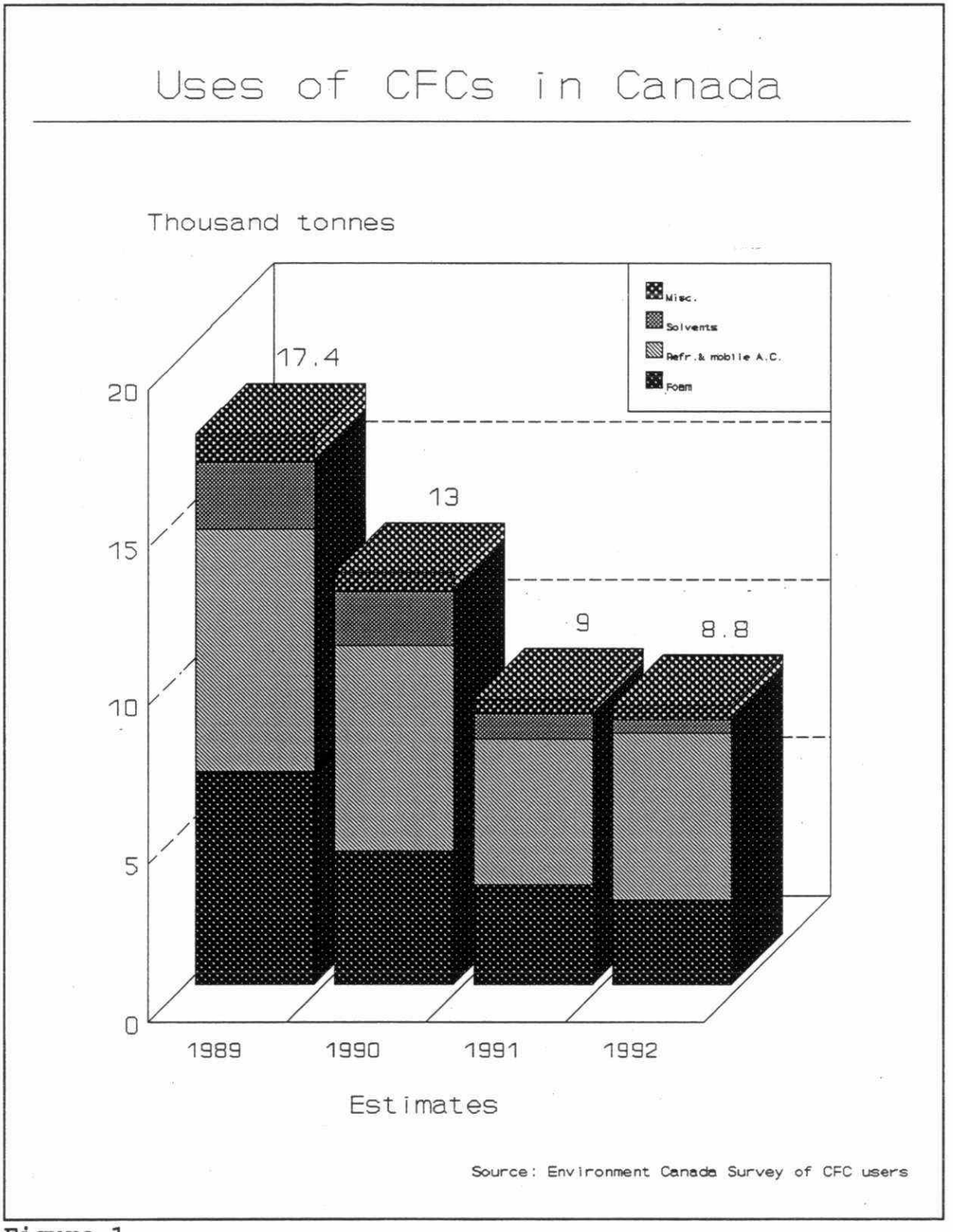

Uses of CFCs in Canada
Thousand tonnes
Misc.
Solvents
Refr.& mobile A.C.
Foam
17.4
13
9
8.8
20
15
10
5
0
1989
1990
1991
1992
Estimates
Source: Environment Canada Survey of CFC users

Figure 1

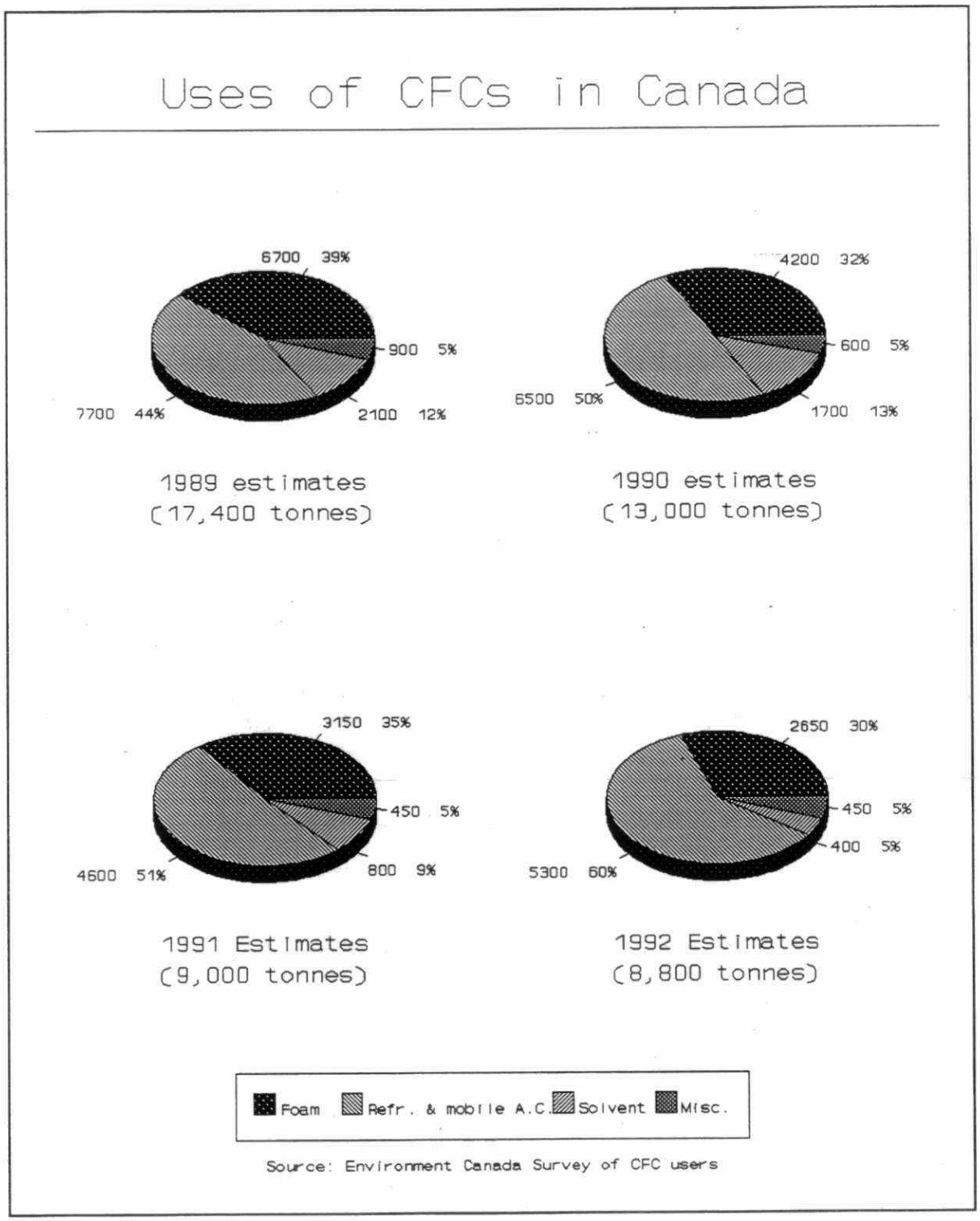

Uses of CFCs in Canada
6700 39%
900 5%
7700 44%
2100 12%
1989 estimates
(17,400 tonnes)
4200 32%
600 5%
6500 50%
1700 13%
1990 estimates
(13,000 tonnes)
3150 35%
450 5%
4600 51%
800 9%
1991 Estimates
(9,000 tonnes)
2650 30%
450 5%
400 5%
5300 60%
1992 Estimates
(8,800 tonnes)
Foam
Refr. & mobile A.C.
Solvent
Misc.
Source: Environment Canada Survey of CFC users

Figure 2

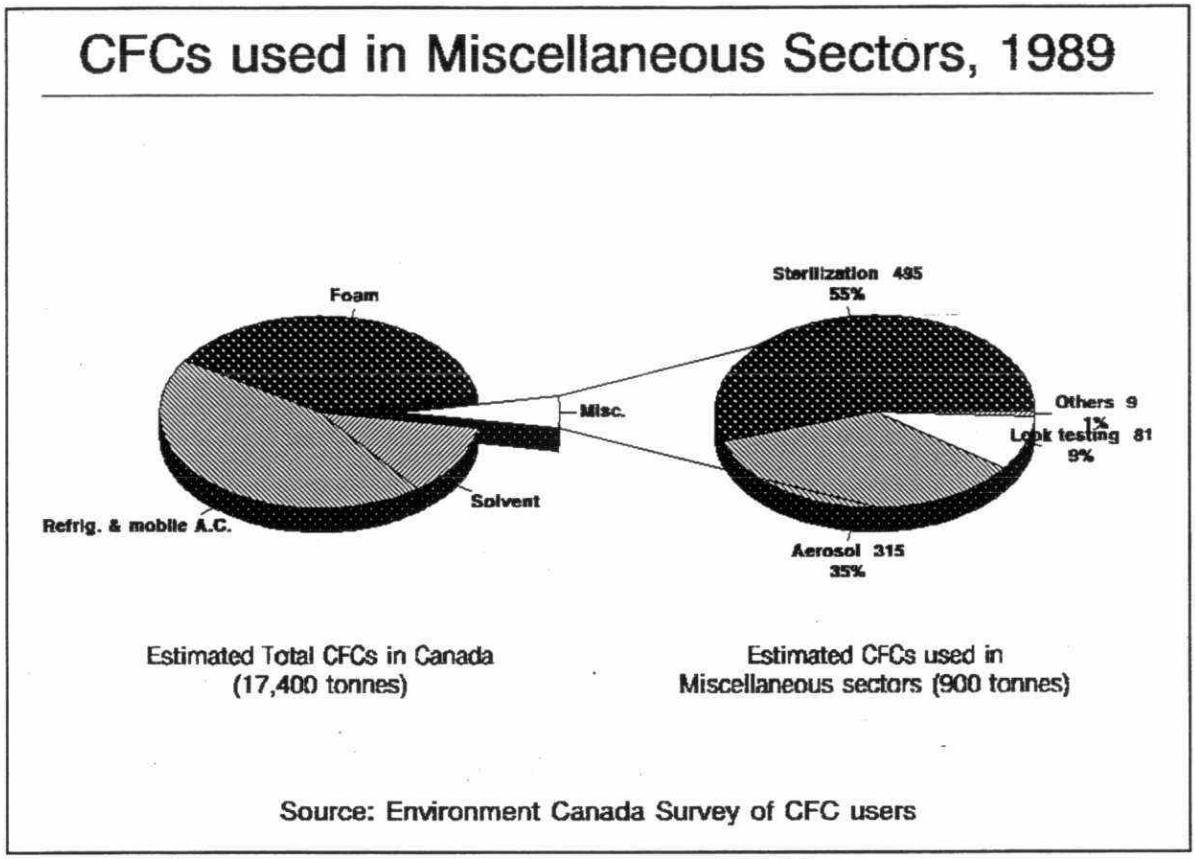

CFCs used in Miscellaneous Sectors, 1989
Foam
Misc.
Solvent
Refrig. & mobile A.C.
Sterilization 495
55%
Others 9
1%
Leak testing 81
9%
Aerosol 315
35%
Estimated Total CFCs in Canada
(17,400 tonnes)
Estimated CFCs used in
Miscellaneous sectors (900 tonnes)
Source: Environment Canada Survey of CFC users

Figure 3

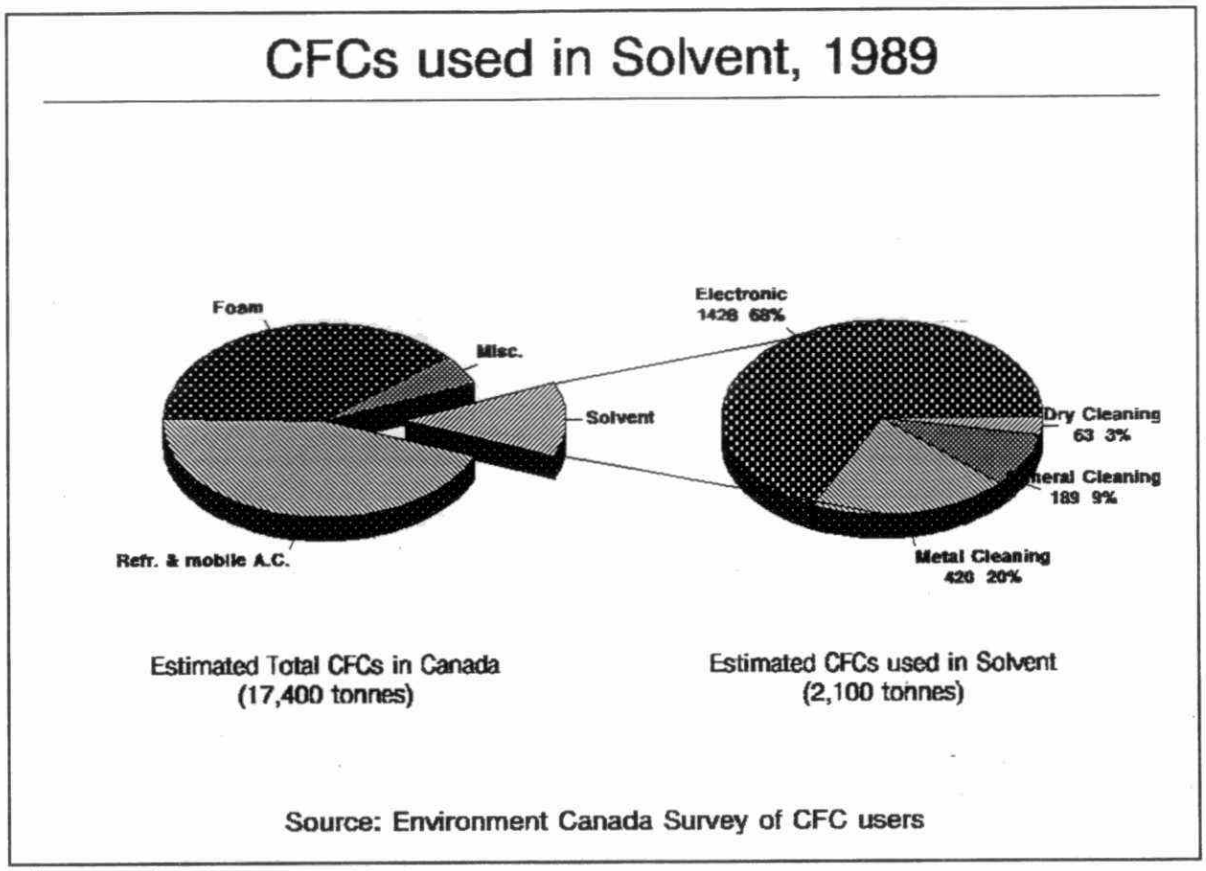
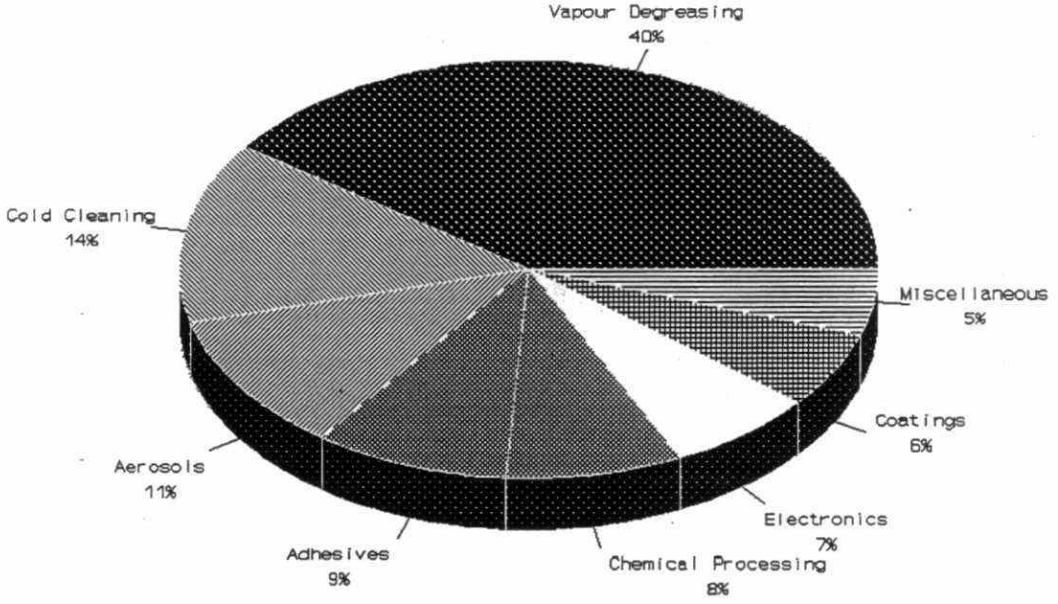

CFCs used in Solvent, 1989
Foam
Misc.
Solvent
Refr. & mobile A.C.
Electronic
1428 68%
Dry Cleaning
63 3%
189 9%
Metal Cleaning
420 20%
Estimated Total CFCs in Canada
(17,400 tonnes)
Estimated CFCs used in Solvent
(2,100 tonnes)
Source: Environment Canada Survey of CFC users

Figure 4

1,1,1-Trichloroethane in Canada (Methyl Chloroform), 1989



Total 1,1,1-Trichloroethane:
16,000 metric tonnes

Source: Dow Chemical Canada estimations and product profiles from Corpus Information Services

2.0 The Threat:

2.1 The Environmental Case Against Ozone-Depleting Substances (ODS):

Ozone-depleting substances such as CFCs and HCFCs are human produced, fluorine, chlorine and/or bromine-containing organic compounds. When released they slowly migrate to the upper atmosphere where they undergo photochemical decomposition, releasing highly-reactive chlorine or bromine atoms. These atoms react with other gases including ozone causing a significant reduction in ozone concentration (each atom can undergo 10,000 - 100,000 reactions) before it is stabilized as hydrochloric or hydrobromic acids. Bromine has more destructive power than chlorine.

The presence of one or more hydrogen atoms in HCFCs reduces their stability in the atmosphere, i.e., HCFCs have a shorter life-time which result in reduced destructive ability to the ozone layer. Other chemicals, such as 1,1,1-trichloroethane (MCF), and CTC also contribute to ozone-depletion.

Solvents are capable of dissolving other toxic substances in landfills. They are highly-mobile and can diffuse through landfill liners and covers and contaminate groundwater. Their high vapour pressure makes them evaporate quickly causing air pollution.

To evaluate the destructive power of an ODS, a measure has been introduced known as the Ozone-Depletion Potential, ODP. It shows how much ozone is destroyed by 1 kilogram of a chemical over a specific period of time. It compares the destructive power of a compound with that of CFC-11 (trichlorofluoromethane) which is given an ODP value of 1.0. [Ref. A Primer on Ozone Depletion, Environment Canada, 30, 1993].

- **Definition:** Ozone Depleting Potential represents the amount of ozone destroyed by emission of a gas over its entire atmospheric lifetime relative to emission of the same mass of CFC-11 (trichlorofluoromethane, lifetime 55 years) which is given an ODP value of 1.0, i.e.
  ODP = Global change in ozone due to an ODS / change in ozone due to CFC-11.

For example, CFC-12 has an ODP of 1.0 and a stratospheric lifetime of 116 years, compared with 0.8 and 110 years for CFC-113, 0.6 and 550 years for CFC-115, 0.02 and 47 years for HCFC-123, 0.02 and 129 years for HCFC-124, 0.07 and 120 years for HCFC-225cb, 0.15% and 240 years for HCFC-22 and 0.2 and 215 years for HCFC-142b.

The concentration of chlorine in the stratosphere was 1.5 ppbv (part per billion by volume) in 1970 compared with 2.5 in 1980 and 3.6 in 1991 with an expected peak value of 4.1 ppbv in the year 2000.

Ozone-depletion allows increased levels of UV-B radiation to reach the earth's surface. The economic impact of UV-B radiation environmental damage to plastic and wood construction materials and forestry could be significant.

Another aquatic environmental impact is the risk of loss of zooplankton and phytoplankton (microscopic marine plant) responsible for storage of 80% of carbon dioxide leading to enhancing greenhouse gases and global warming. The larvae of many fish are susceptible to harm from UV-B radiation as they spend part of their life near the surface of water. Increased UV-B penetration has also been shown to cause adverse effects on plants and crops.

As well, cloud patterns are affected by phytoplankton losses. In addition, CFCs also absorb light in the infrared range, making CFCs contributors to climate change.

The elimination of CFC-113 and MCF solvent-cleaning will result in less volatile organic compounds (VOC) emissions if compared with low-solid soldering and alcohol formulations and, therefore, less contributions to ground-level ozone (smog).

The use of no-soldering technologies eliminates post-soldering solvent cleaning and thereby reduces the amount of hazardous waste produced.

2.2 Effects of Ozone-Depletion on Life and Human Health:

The increase in UV-B radiation can cause known adverse effects on plants, insects, birds, fish and animals. Decreased growth of fruits, vegetables and trees has also been reported. Skin cancer and eye tumours due to UV-B exposure were observed in domestic animals.

Exposure to UV-B radiation has been identified as a cause of two types of non-melanoma skin cancers: squamous cell cancer and basal cell cancer. Research results suggest that UV-B radiation plays an important role in causing malignant melanoma skin cancer.

Recent studies in Canada show that out of 50,000 new cases of skin cancer were expected in 1992 as a result of UVB-radiation exposure. Out of these new cases of skin cancer, 3100 are characterized as lethal (melanoma) and 570 have resulted in death, making skin cancer the fastest growing cancer. The cost of skin cancer treatment in 1992 was estimated at $50 million. [Ref. Canadian Cancer Statistics.]

Human exposure to UV-B radiation may cause eye damage leading to the development of cataracts and could adversely affect the retina. 10% thinning of the ozone layer will result in 2 million new cases of cataracts globally.

It was also reported that UV-B radiation weakens the immune system and reduces the body's ability against infections.

Increased penetration of UV-B radiation may increase the rate of ground-level ozone formation. Exposure to the latter may lead to chronic health effects, including morphological changes to, and impaired function of, the lungs.

There are, however, several occupational health issues which should be considered with no-soldering as an alternative technology, i.e., to avoid prolonged exposure to alcohols and formic acid.

3. Solvent Uses and Alternatives:

Solvents are used for **cleaning** in a variety of manufacturing processes, **in adhesives**, in **paints** and **inks** and in **dry cleaning.** About 85% of methyl chloroform and 97% of CFC-113 are used for cleaning which consists of four main cleaning categories:

- **Cold cleaning** can be a batch, continuous or in-line cleaning process carried out in pails, vats, tanks or automated equipment with vertical or ultrasonic agitation or spray cleaning.

- **Vapour degreasing** is usually accomplished in a steel tank with steam or electrical heating coils and condensing coils. These can be open-top (batch cleaning) or in line. Vapour cleaning may be augmented by immersion or spraying.

- **Wipe cleaning** is generally performed by small operators or for large parts (airplanes assembly).

- **Spraying and flushing** equipment usually consists of a solvent tank, feeder hose, spray gun, over-spray containment and baskets to hold the parts during cleaning and is used for cleaning outer metal surfaces.

Cleaning equipment manufacturers that use solvents are located primarily in the United States with distributors in Ontario and the rest of Canada.

About 70% of the 160 tonnes of CFC-113 used as solvents annually in Ontario are used for cleaning in electronics manufacturing. Only 7% of methyl chloroform consumption (≈ 350 tonnes per year) are utilised by electronics manufacturers while more than 50% of the annual consumption of this chemical is used for metal cleaning by metal finishing, steel, plastics and automotive manufacturers in Ontario.

There are hundreds of users of CFC-113 and methyl chloroform, many of which are small businesses with less than 100 employees. However, a complete inventory of users is not yet available.

Methyl chloroform and CFC-113 solvents are being recovered in Ontario by such firms as Anachemia and Safety Kleen. The latter company takes CFC-113 and methyl chloroform wastes to the U.S. where they are processed and repackaged. Quantities being recovered and recycled are not known.

There are many different chemicals and technologies that can be used in place of ozone depleting cleaning solvents. There are also a wide variety of users, uses and applications that range from small batch operations to large continuous, automated production lines. Consequently, it is not possible to define "typical users"

or "generic cleaning systems" on which to base representative estimates of ODS emission reductions or the costs of installation and operation.

Uses, alternatives and benefits/concerns for MCF, CFC-113, CTC and HCFCs are presented in **Appendix A.**

3.1 Alternative Cleaning Chemicals and Technologies

Substitute cleaning chemicals for CFC-113 and methyl chloroform include:

- Other chlorinated solvents;
- Organic solvents;
- Hydrocarbons;
- Perfluorocarbons;
- HCFCs

Alternative cleaning systems include:

- Semi-aqueous cleaning;
- Aqueous cleaning;
- Non-solvent cleaning technologies;
- No-clean production systems

Alternatives range from "drop in" chemicals, such as HCFCs, which can be substitutes for existing solvents without retrofitting difficulty or costs, to the purchase and installation of new cleaning equipment which involves revising the entire production process. For example, drop-in chemicals can be applied to vapour degreasing units. However, aqueous and semi-aqueous cleaning systems generally require new equipment and more floor space than existing solvent systems.

Substitute cleaning chemicals and alternative cleaning systems are described below.

Semi-aqueous cleaning involves the use of an organic cleaning formulation followed by water washing and drying stages. Rust inhibitors and surfactants may be added. Both the wash and rinse stages are recirculating so the solutions are not continually discharged. According to the UN Environmental Program documentation, there are many different aqueous and semi-aqueous cleaners and cleaning systems on the market.

It is generally necessary to purchase and install new semi-aqueous equipment rather than retrofit existing equipment. Consequently this system is more costly to implement than ODS systems. Furthermore, new wastewater disposal or treatment facilities may have to be installed.

Aqueous (water-based) cleaning involves wash, rinse and dry stages with an alkaline, aqueous solution. Aqueous cleaning is used mainly for metals cleaning and is often preferred because it is less costly than solvent cleaning. However, water-based cleaning cannot be used where the metals are subject to oxidation (rust).

Where high degrees of cleaning and drying are not required or where low volumes of parts are cleaned, retrofitting existing equipment may be possible; otherwise new equipment will be required. According to the U. S. EPA/ICLOP report, "Aqueous and Semi-Aqueous Alternatives for CFC-113 and Methyl Chloroform Cleaning of Printed Circuit Board Assemblies", in-line aqueous cleaning systems for printed circuit boards can cost between $40,000 to $150,000 U.S. to install.

Aqueous cleaning systems may be less costly than solvent-based vapour degreasing systems because chemical and waste disposal costs are lower, especially for large manufacturers. New closed-loop aqueous cleaners can minimize wastewater discharges by recycling the water. A U. S. study suggests that a complete production line using an aqueous-alkaline system requires the same magnitude of investment as solvent-based systems but annual operating costs are lower for the aqueous system.

Organic solvents such as alcohols, ethers, esters and ketones can be used in place of CFC-113 and methyl chloroform in certain precision, metal and electronics cleaning operations. If these compounds are heated to increase solvency, equipment designed to control vapour losses must be used.

Isopropanol and acetone have a proven record of precision cleaning applications and can be introduced for relatively low cost into existing CFC equipment.

Petroleum and Aromatic Hydrocarbons such as petroleum derivatives, isopropyl alcohol, acetone, and methyl ethyl ketone are generally good cleaners and evaporate readily. Petroleum solvents including mineral spirits, naphtha, kerosene and Stoddard solvent, have long been popular in the precision metalworking industry.

Aromatic hydrocarbons such as toluene and xylene are frequently used for dipping or wiping. However, toluene and xylene are very reactive VOCs and are the target of regulatory actions and control in many jurisdictions, even though toluene has been assessed as "non-toxic" under the Canadian Environmental Protection Act.

A major disadvantage of these compounds is their high flammability. It is, therefore, unlikely that petroleum-based

solvents will be widely used as substitutes for ODS solvents.

Perfluorocarbons (PFC) are "fully fluorinated" compounds whereas CFC, HCFCs or HFCs contain chlorine. PCFs have the potential for use in a wide variety of cleaning operations but they are more expensive than CFCs or HCFCs. The U.S.-EPA has stated that PFCs may be the only substitutes available for some uses. PFCs are viewed by some industrial sources as important, but transitional, substitute chemicals.

"No-Clean" Alternatives involve eliminating the cleaning stage altogether from the manufacturing process. The electronics industry has developed no-clean processes that eliminate the need for CFC-113 or methyl chloroform. One such process is controlled atmosphere soldering with ice-particle cleaning technology.

Some larger electronics manufacturers are introducing no-clean flux processes. Flux is a chemical used in soldering which must be removed from the component after the soldering is complete. According to Environment Canada this process change is expensive and is unlikely to be pursued by the smaller firms until a less expensive substitute becomes available.

Few "no-clean" options are available for metals fabrication because oils are used extensively as lubricants which must be removed from the final product. No-clean approaches and products, such as "vanishing" oils, are being developed for cleaning metal parts and may soon be more broadly available.

Where the cleaning step is eliminated, there are no costs for cleaning solvents and equipment or for operation. Moreover, space savings and process simplification can be realised.

Non-solvent Cleaning Technologies include supercritical carbon dioxide and CO_2 snow; plasma cleaning using electrically charged gases for precision cleaning; filtered, contaminant-free pressurized gas or air (not effective for microscopic particles), and ultraviolet light combined with ozone. Thermal vacuum de-oiling uses a heated vacuum chamber to remove oil from metal parts by vaporizing the oil.

Most of these technologies are very costly and a few appear to have limited application. Nevertheless, these technologies may be the best available alternative for some applications.

HCFCs are considered interim substitutes for CFC-113 and methyl chloroform as degreasers because of their similar physical properties and cleaning ability.

Substitution with HCFC-141b and HCFC-123 would involve

equipment changes and would be substantially more costly than if HCFC-225 were used. HCFC-225 solvents are virtually "drop-in" replacement chemicals requiring little or no equipment changes (Env. Can 1990). HCFC 225ca and 225cb appear to have the potential to replace CFC-113 in certain precision cleaning applications, such as computer hard disk drives, gyroscopes, optical components and hydraulic control systems.

Other Chlorinated Solvents such as trichloroethylene, perchloroethylene and methylene chloride can be used alone or in combination with other processes. However, trichloroethylene and perchloroethylene generate volatile organic compound emissions (VOCs) which are targeted for control and reduction by the federal and provincial governments. Moreover, users of chlorinated solvents face rising costs to manage, treat and dispose of the these chemicals as wastes.

The Ministry of Labour may require certain operational changes by users of chlorinated solvents to ensure compliance with indoor air quality standards (50 ppm for Perc-Occupational Health & Safety) including venting outside buildings. Any system vented outside or changes to be vented outside will need Part 9 EPA approval from MOEE for a process such as change of solvent and other equipment changes.

Uses of alternative solvents, particularly chlorinated solvents, will also be impacted by restrictions on the disposal of subject waste (Regulation 347) and restrictions in local sewer use bylaws.

These three solvents were used widely for metal degreasing and cleaning until concerns about their toxicity prompted a shift to methyl chloroform. The change back to these chemicals may be facilitated by the availability of new processes and systems that reduce the release or discharge of these chemicals. Such equipment can be purchased in Ontario.

However, ICI Canada Inc. ceased production of trichloroethylene in Canada in 1985 while Dow Canada stopped making perchloroethylene in 1992. Canadian demand for these chemicals is now met by imports from the U.S. or Europe.

3.2 Substitutes for Carbon Tetrachloride

Carbon tetrachloride is not widely used as a cleaning solvent because of its toxicity. No replacement for carbon tetrachloride will be required because many of its applications are being phased out. In other non-solvent uses, carbon tetrachloride is chemically transformed or completely destroyed or recycled. These applications include: feedstock for CFC manufacture; feedstock for making other chlorinated hydrocarbons; as a

pharmaceutical or agrochemical feedstock; and as a catalyst "sweetener". No substitute has yet been found for the use of carbon tetrachloride as an inert solvent in chlorination reactions.

3.3 Alternatives for Adhesives, Dry-Cleaning, Coatings and Inks, and Aerosols

Adhesives constitute about 9% of Ontario consumption of methyl chloroform. Furthermore, adhesives containing methyl chloroform comprise only 2-3% of the total adhesives market.

The range of applications and performance requirements for this application is diverse and there is no single substitute chemical for methyl chloroform for all uses. Cost savings are claimed for water-based adhesives and this has apparently induced a trend away from solvent-based adhesives. Savings come from using modified solvent equipment, easier cleaning during manufacturing and storage of products in less costly containers.

Other substitutes include hot-melt adhesives, radiation curing and high solid formulations. Although hot-melt adhesives are more expensive per unit of formulated weight, greater strength allows less material used and reduced overall costs. However, hot-melt adhesives are an anathema to paper recycling.

Radiation cured adhesives have a longer shelf-life than most adhesives and their use leads to production of a more reliable product, lower rejection rates and labour costs and reduced cleanup and inspection times. Radiation cured adhesives are an option only for new facilities if existing equipment cannot be retrofitted.

High solids adhesives cost more and perform worse than solvent-borne adhesives.

Dry-Cleaning establishments are minor users of CFC-113 and MCF. Perchloroethylene is the most widely used dry-cleaning solvent and a viable substitute for CFC-113 and MCF. Dry-cleaning machines that use CFC-113 can be retrofitted to accept different solvents.

Similarly, machines using MCF, can be modified to use perchloro-ethylene. According to the Ontario Dry Cleaners and Launderers Institute, phasing out CFC-113 and MCF is of little concern to their cleaning business because only 10 establishments use methyl chloroform in Canada and only 1% of all dry cleaners use CFC-113.

Substitutes for **Coatings and Inks** which contain MCF include water-based, high solids and powder formulations. Some of the substitutes are flammable, therefore improved handling and storage facilities may be required. Solvent recovery systems can capture emissions that result from evaporation during production. In some water-based coatings, solvents are added for ease of application but these contain less solvent than conventional coatings.

Continued growth in the use of aquous inks has been forecast by industry sources.

Substitutes for **Aerosols** include petroleum distillates, water-based formulations, HCFCs, HCFC blends and alternative delivery systems. Alternatives are not yet available for all applications that require non-flammable substitutes such as customer-applied water and oil repellents, spot removers and suede protectors; mould releasers; and electronics and brake cleaners. It is expected that costs will be high initially for applications where there are no alternatives until more moderately priced options became available. solvent alternatives.

Table 3.1 presents some environmental considerations for solvent alternatives:

Solvent		Env. Canada's. Priority Substances List	Volatile Organic Compounds	Identified With Other Environmental Issues (eg. Greenhouse gases)	Occupational Health & Safety [2]
Ozone Depleting Substances	CFC-113	No	No	Yes	No
	Methyl chloroform	Yes	No	Yes	No
	Carbon tetra-chloride[1]	No	No		Yes
	HCFCs	No	No	Yes	Yes
Other Chlorinated Solvents	Trichloroethylene	Yes	Yes	Yes	Yes
	Perchloroethylene	Yes	Yes	Yes	Yes
	Methylene chloride	Yes	No	Yes	Yes
Hydro-carbons	Naphtha (aliphatic)	No	Yes	No	No
	Toluene (aromatic)	Yes	Yes		Yes
	Xylene (aromatic)	Yes	Yes		Yes
Other Organic	Alcohols	No	Yes		Variable
	Ketones	No	Yes		Yes
	Glycol ethers	No	Yes		Yes
Perfluorocarbons		No	No	Yes	No
Terpenes		No	Yes		Variable

Source: Energy Pathways Inc. (1993) - format changed
[1] Information not found in the original chart.
[2] Solvents with a threshold limit value of 100 ppm or lower are all considered to have potential occupational health and safety concerns.

4. Economic Implications of Solvent Uses and Technologies:

The purpose of this section is to summarize market structure and technical information about the production, distribution and use of solvents.

Markets for solvents consist of producers, distributers and customers or users of solvents together with firms that produce or distribute any associated cleaning equipment.

4.1 Market Structure and Uses

CFC-113 and methyl chloroform are no longer produced in Canada although Dow Chemicals Canada was the sole Canadian producer before it ceased output. Consequently, all CFC-113 used in Canada is imported from the U. S. where it is manufactured by Dupont, ICI and Allied-Signal. Methyl chloroform is imported from Dow in the United States and from ICI in the United Kingdom (through ICI Canada).

Carbon tetrachloride is manufactured in Canada by Cornwall Chemicals in Cornwall, Ontario, and by Dow Canada. Allied-Signal and Dupont Canada ceased all production during 1992-3.

Between 1988 and 1992, the value of methyl chloroform imports ranged from $1.8 M (1989) and $8.8 M (1992) while exports were valued at between $120,000 (1991) and $3.4 M (1989). During this same period, the value CFC imports has remained at $23 M for the period 1989 - 1991 but jumped to $27.3 M during 1992. Exports varied between $1.1 M (1990) and a surprising $16.2 M (1992).

Canada is a net exporter of carbon tetrachloride. Between 1988 and 1992, the value of exports ranged from $2.6 M (1992) to $6.2 M (1989) while imports were valued between $120,000 (1989) and $630,000 (1991).

These import/export values represent a part of the value of the markets for these commodities. Total revenues generated by these chemicals in Ontario may be approximated by multiplying the consumption figures by prices. Using conservative prices, the total revenues associated with each chemical are noted below:

CFCs =	8,835 t/yr	x	$3,000/t	=	$26.5 M/yr
MCF =	12,500 t/yr	x	$1,000/t	=	$12.5 M/yr
CTC =	540 t/yr	x	$ 500/t	=	0.3 M/yr
Total					$39.3 M/yr

Producers sell their solvent directly to users or through chemical distributors. For example, Dupont sells solvents to Canadian Colours & Chemicals Limited as well as to Van Water & Rogers. The majority of Dow Chemical sales of methyl chloroform is through chemical distributors. Dow Canada's customers consist of the firms that are customers of Dupont plus Ashland Chemicals. Cornwall Chemicals distributes carbon tetrachloride through a single distributor, Stanchem.

As shown in Table 4.1, less than 5% of total CFCs used in Canada are solvents (ie. 400 tonnes out of 8,835 tonnes of all types of CFCs consumed in Canada during 1992). According to a 1991 Environment Canada study, solvent use during 1990 across provinces amounted to 39% in Ontario, 21% in Quebec, 19% in Alberta, 9% in British Columbia and 12% in all other provinces. Using 40% as the proportion of all CFCs consumed in Ontario, an estimated 160 tonnes of CFCs were sold and used as solvents, which is equal to 4.5% of total Ontario CFC usage.

Table 4.1
CONSUMPTION OF CFCs IN CANADA AND ONTARIO, 1992

Uses	CFCs-Canada (Tonnes)	CFCs-Ontario (Tonnes) (1)	HCFCs-Canada (Tonnes)	HCFCs-Ontario (Tonnes)
Solvent	400 (4.5%)	160 (4.5%)	(2)	(2)
Sterilization	300 (3.4%)	120 (3.4%)	(2)	(2)
Mobile Air Conditioning	3,600 (41%)	1,443 (41%)	(2)	(2)
Foam Manufacturing	2,650 (30%)	1,056 (30%)	3,360 (48%)	1,344 (48%)
Refrigeration & Air Conditioning	1,700 (19%)	669 (19%)	3,430 (49%)	1,372 (49%)
Aerosol	143 (1.6%)	57 (1.6%)	(2)	(2)
Leak Testing	38 (0.4%)	15 (0.4%)	(2)	(2)
Other	4 (0.05%)	1.6 (0.05%)	210 (0.03%)	84 (0.03%)
Total	8,835 (100%)	3,521.6 (100%)	7,000 (100%)	2,800 (100%)

Source: Environment Canada.

(1) Based on 40% of total CFC consumption Data for Canada.
(2) No consumption in this use category at this time.

As shown in Table 4.2, about 5,216 metric tonnes of methyl chloroform and carbon tetrachloride are consumed in Ontario annually.

Table 4.2 ESTIMATED ANNUAL CONSUMPTION OF METHYL CHLOROFORM AND CARBON TETRACHLORIDE AS SOLVENTS IN CANADA AND ONTARIO

ODS Chemicals	Canada (Tonnes)	Ontario (Tonnes) (1)
Methyl Chloroform	12,500 (1992)	5,000 (1992)
Carbon Tetrachloride	540 (1990)	216 (1990)
Total	≈ 13,040	≈ 5,216

Source: Environment Canada

(1) Based on assuming 40% of Canadian use.

The distribution of consumption of these chemicals among different uses and sectors is shown in Appendix A. As noted, about 4.5% of total CFC consumption, 100% of methyl chloroform produced and sold and about 3% of carbon tetrachloride consumed are used as solvents.

These estimates indicate that, out of a total 5,400 tonnes of ODS solvents used in Ontario annually, methyl chloroform is the dominant solvent with the combined amounts of carbon tetrachloride and CFCs accounting for only 7% of total solvent use in Ontario.

Weighting the amount of each ODS solvent consumed by its ODP value, as shown in Table 4.3, still has methyl chloroform as the dominant chemical.

Table 4.3
CONSUMPTION OF ODS SOLVENTS IN ONTARIO WEIGHTED BY ODP VALUES

ODS Chemicals	Ontario Consumption Tonnes/yr	ODP Values	Weighted Cons. Tonnes/yr
CFC-113	160	0.8	128.0
Methyl chloroform	5,000	0.12	600.0
Carbon tetrachloride	216	1.1	237.6

Prices of ODS have been rising in recent years as a result of restrictions on their production while demand by users continues. Prices quoted in Table 4.4 indicate that new CFC solvents are currently sold for between $8,000 - $12,000 per metric tonne while new methyl chloroform is priced from $1,500 to $2,500 per tonne, depending on the quantities purchased. The price of CFC-113 has increased by as much as 70% over the past 2 years. Recycled product is sold for between 1/3 to 1/4 of the price of new material.

Table 4.4
CURRENT (1993-94) CANADIAN PRICES OF CFC-113, METHYL CHLOROFORM, CARBON TETRACHLORIDE AND HCFC

OZONE DEPLETING SUBSTANCE	1993-1994 PRICES (1)	
	$/kg	$/tonne
CFC 113 - New	$8 - $12	$8,000 - $12,000
CFC 113 - Recycled/reclaimed	$2 - $4	$2,000 - $4,000
METHYL CHLOROFORM - New	$1.50 - $2.50 (2)	$1,500 - $2,500
METHYL CHLOROFORM - Recycled/reclaimed	$1.00 (2)	$1,000
CARBON TETRACHLORIDE	$0.60	$600
HCFC	$8.50 - $10.00 varies with blend	$8,500 - $10,000

(1) Prices vary according to quantity sold.
(2) Price to distributors. Prices to final users will be higher.

A key factor affecting the use of CFC and MCF solvents has been military procurement specifications which have required the use of CFC-113 in cleaning precision parts or electronics components. In 1990, the U. S. Defense Department altered its rules to specify performance rather than product usage. The Canadian government is reviewing its own military specification to determine whether there are any conflicts.

Currently, demand for HCFCs is small although prices are close to those of CFCs. Dupont reports that 100 kg of HCFCs were sold for solvent use in the first nine months of 1992. Other distributors include Allied-Signal, Elf Atochem North America Inc., Tech Spray Inc. and ICI Canada.

Expansion of production and use of HCFCs is uncertain because of added investment that will be required of both producers and users and the fact that HCFCs may be subject to bans or restrictions under the proposed federal Regulation. Consequently, HCFCs may not be used widely as substitute or transitional materials at all.

Tables 4.5, 4.6 and 4.7 present the 1992 estimates of use, consumption and principal users of CFC-113, MCF and CTC in Ontario.

Table 4.5
CFC-113 USE, CONSUMPTION AND PRINCIPLE USERS, 1992 ONTARIO ESTIMATES

Uses	Annual Consumption (1) (Tonnes)	Industry Which Use the Solvent (2)	Main Products Affected (3)
Electronics Cleaning	109 (68%)	• computer • manufacturing (entertainment, telecommunications, military, medical equipment & home electronics) • automotive (brakes and motor)	• circuit boards
Metal Cleaning (includes precision cleaning (3))	32 (20%)	• metal finishing • steel • manufacturing • computer • plastics (precision)	• optical equipment • medical equipment • gyroscopes • computer disks • disk drives • micro-switches • hydraulic control systems • electrical contacts • plastic assemblies
General Cleaning	14 (9%)	• plastics • automotive • manufacturing	• adhesive spreading machinery • xerox and laser printing machines • auto engine parts and power trains • industrial handling equipment (hoists, cranes etc.) • metal working machinery • sport and leisure (cameras, TV & radio, bicycles etc.)
Dry Cleaning	5 (3%)	• dry cleaning	• clothing
Total	160 (100%)		

Source: Environment Canada

(1) Based on 40% of total Canadian use.
(2) List is not all comprehensive.
(3) Cleaning of sensory devices.

Table 4.6
METHYL CHLOROFORM USE, CONSUMPTION AND PRINCIPLE USERS, 1990 ONTARIO ESTIMATES

Uses	Annual Consumption (Tonnes) (2)	Industry Which Use The Solvent (3)	Main Products Affected (3)
Electronics	350 (7%)	• computer • manufacturing (entertainment, telecommunications, military, medical equipment & home electronics) • automotive (brakes and motor)	• circuit boards • semiconductors (wafers & integrated circuits)
Metal Cleaning(1)	2,700 (54%)	• metal finishing • steel • manufacturing • plastics • automotive	• optical equipment • medical equipment • gyroscopes • computer disks • disk drives • micro-switches • hydraulic control systems • electrical contacts • plastic assemblies
Adhesives	450 (9%)	• Health care • Manufacturing • Electronics • Textiles • Publishing	• medical and dental uses • transport • consumer products • electronics • communications • bookbinding • textiles • laminating
Coatings	300 (6%)	• Manufacturing • Automotive • Appliance • Construction	• furniture • car electronics • metal containers • structural steel • appliances • construction equipment
Miscellaneous (4)	1,200 (24%)	• Aerospace • Electronics • Manufacturing • Dry Cleaning • Aerosols	• film cleaning • products from moulds • electrical components
Total	5,000 (100%)		

Source: Environment Canada

(1) Cleaning of sensory devices.
(2) Based on 40% of total Canadian use.
(3) List is not inclusive.
(4) lubricant bearers, vapour-phase soldering, drying, aerosols, chemical processing systems.

Table 4.7
CARBON TETRACHLORIDE USE, CONSUMPTION AND PRINCIPLE USERS, 1992 ONTARIO ESTIMATES

Uses	Annual Consumption (2) (Tonnes)	Industry Which Use The Solvent (3)	Main Products (3)
Feedstock for CFC-11, 12 (1)	6,984 (97%)	• None in Canada	
Solvent Uses • Inert solvent in chlorination reactions; • Production of chlorine; • Feedstock for other chlorinated hydrocarbons.	216 (3%)	• Chlor-alkali (Chlorine manufacturing) • Oil Refining • Laboratories (eg. Ministry of Environment and Energy) • Pharmaceuticals and agrochemicals manufacturing	• chlorinated rubber • laboratory testing (extraction solvent, chromatography solvent , reaction medium for synthetic chemistry, solvent for spectroscopy as an analytical standard and in Karl Fischer reagent in testing laboratories) • catalyst promoter in oil refineries • marine and weatherproof paints • the drug Ibuprofen, AZT, Dalacin and intermediate trityl chloride) • pesticides (chlorathanil, DCPA, picloram, permethrin and cypermethrin)

Source: Environment Canada

(1) Production of CFC-11 & 12 terminated in Canada in early 1993.
(2) Based on 40% of total Canadian use.
(3) List is not all inclusive.

5.0 Regulatory Activity in Other Jurisdictions:

Governments around the world recognize the threat posed by stratospheric ozone-depletion. There is wide agreement among 125 countries signatories to the Montreal Protocol that the production and use of ozone-depleting substances must be phased-out.

Some countries such as Switzerland, Sweden, Germany, Denmark, Australia, the Netherlands, the United States, Canada and members of the European Community are phasing-out ODS faster than required by the Montreal Protocol schedules.

In Germany, the use of CFC-113 and MCF was prohibited effective December 1992 for use in surface treatment, dry-cleaning, textile finishing and chemical extraction. Temporary exemptions may be granted for absolutely necessary applications but under stringent emission-control requirements.

Furthermore, the production of solvents containing controlled substances were halted in January 1992. As a result, German industries were to replace ODS solvents by January 1, 1993 as required by legislation and to eliminate the use of CFC-113 and MCF entirely by 1994.

Despite the technical feasibility of phasing-out ODS solvents by 1994, German industry was facing a number of problems:
- not all solvent users, especially small businesses, were aware of the phase-out dates;
- shortage of technical experts and information on solvent alternatives and applications;
- possible delays in supplies of solvents and/or equipment.

Members of the European Free Trade Agreement (EFTA) have also adopted measures to completely phase-out halogenated ODS. Norway and Sweden have eliminated the use of CFC-113 in all applications except in textiles and dry-cleaning as of January, 1991.
Austria, Finland, Sweden and Norway will phase-out the use of CFC-113 in all applications by January, 1995.

In fact, the regulation set by the European Community (EC) for the phase-out of CFC-113 is more stringent than the Montreal Protocol, and is demonstrated by the EC 85% reduction of CFC-113 by January 1, 1994. In addition, members of the EC are allowed to exceed these measures for the protection of the ozone layer.

In Singapore, Digital Equipment Corporation has replaced (1991) CFC solvents with an aqueous process originally developed in Washington, D.C. for cleaning surface-mounted computer products.

In Japan, Hitachi Construction Machinery Co. reduced its CFC-113 consumption from 15 m. tonnes to 0.6 tonnes in 1988, and MCF from 220 tonnes to a phase-out in 1998. A complete phase-out of CFCs is

planned in 1995. Large reduction of CFC-113 and MCF were made by the Nissan Electric Company. In 1992, the Nissan Motor Company has replaced CFC-113 and MCF with aqueous cleaning and was to phase-out CFCs entirely in 1994 using HFCs as alternatives.

The Ministry of International Trade and Industry in Japan has requested its 72 industrial associations to phase-out CFC and MCF by the end of 1995.

5.1 International Agreements to Phase-out CFCs:

Negotiations by the *United Nations Environment Program* (UNEP) resulted in the *Vienna Convention* for the protection of the ozone layer, March 1985. The Convention provided a framework for international cooperation in research, environmental monitoring and information exchange. In September 1987, 24 nations signed the *Montreal Protocol* on substances that deplete the ozone layer. (ODS). As of September 1991, this number has increased to 75 nations and was geared towards limiting the production, import and export of specific CFCs. Now, over 125 countries have signed the Protocol.

Definitions:
Consumption = production + import - export
Production = amount produced - amount stored - amount of feedstock used to produce other substances
Note: The amount recycled is not considered "production".

In June 1990, parties to *Montreal Protocol* met in London and agreed to more stringent controls on ODS in the original Protocol and added other ODS including carbon tetrachloride and methyl chloroform. The *London Amendments and the Copenhagen Amendments* to the *Montreal Protocol* which have entered into force in November, 1992 are shown in Table 5.1.

According to the *Copenhagen Amendments*, the deadline for phase-out of CFCs was advanced to January 1, 1996, with a 75% reduction set for January 1, 1994. Methyl chloroform and carbon tetrachloride will be phased-out in developed countries by January 1, 1996. HCFC will be capped in 1996 at the 1989 level with a 35% reduction by 2004, 65% by 2010, 90% by 2015 and a complete phase-out by 2030. Parties to the Protocol are also encouraged to limit the use of HCFCs to essentials. Advancement of phase-out dates cannot be ruled out.

The phase-out schedule for developing countries was unchanged from the London meeting of parties (2010 for CFC-113 and 2015 for methyl chloroform with a vote on further acceleration scheduled for 1995. HCFCs are not yet controlled for developing countries.

Parties to the Protocol recognize the importance of a commitment from the international community to control ODS.

However, not all nations were signatories to the Montreal Protocol or committed to its implementation (e.g., Russia and some East European countries). Subsequent meetings were held to reaffirm commitments, to add new substances to the list of those being restricted and to set additional deadlines.

A special fund, Multilateral Fund, in the amount of $240 million over three years was created to assist the developing countries in covering the new cost and will encourage others to join the effort.

Table 5.1: Synopsis of Negotiated Reductions in Ozone-Depleting Substances - Copenhagen Amendments:

Year	CFCs	Halons	MCF	CTC	Methyl Bromide	HCFCs
1994	75% cut	100% cut	50% cut			
1995				85% cut	cap	
1996	100% cut		100% cut	100% cut		cap
2004						35% cut

5.2 Regulatory Activity in the United States:

The United States has included several provisions pertaining to stratospheric ozone protection in the U. S. Clean Air Act of 1990 (CAA, 1990). Sections 602-612 of the CAA, 1990 identifies ozone depleting substances to be regulated (which include solvents), specifies phase-out time-tables consistent with international agreements and gives rules for labelling products that contain, or were manufactured with, Class 1 and Class 2 ODS and containers in which these substances have been purchased or stored. Production of Class 1 substances, which include methyl chloroform and carbon tetrachloride as well as CFCs, is to be eliminated by Jan. 1, 1996.

The development of regulations in the USA, such as the 1990 amendments to the Federal Clean Air Act, for strict control of solvents are making their use both impractical and uneconomical. The 1984 amendments to the Resource Conservation and Recovery Act (RCRA) ban the disposal of halogenated solvents on land. Furthermore, the Federal Pollution Prevention Act reinforces the Superfund Amendments and Re-authorization Act (SARA) Title III by requiring industry to disclose all toxic chemicals used including halogenated solvents, and the establishment of a national toxic chemical emissions inventory.

The EPA has established a government-industry program for voluntary emissions reduction of 17 toxic substances including methyl chloroform (MCF) by 33% in 1992, and by 50% by 1995.

Also, an EPA 1991 policy offers generators up to six extra years to comply with the Clean Air Act pollutant concentration limits in exchange for a significant reduction in pollutant emissions. Industry may use this opportunity for meeting emissions standards by reducing their use of halogenated solvents.

The Clean Air Act (CAA) is currently being amended to reflect the Copenhagen ODS phase-out schedule. Regulations banning nonessential products, including CFC-containing solvents used in electronics and photographic cleaning, were published on January 15, 1993.

The State of Massachusetts has developed a program that requires both public disclosure and the development of plans for the reduction of use and toxic chemicals.

In California, several programs were developed to assist users in phasing-out CFC-113, MCF and other cleaning solvents by regulation or by granting exemptions from existing legislations.

Furthermore, the Source Reduction Research Partnership (SRRP) was established by Metropolitan and Environmental Research Funds to enhance the reduction of halogenated solvents use. Consideration was given to: current solvent use, economic impact, time, customer attitudes, regulatory compliance, implementation barriers, training and monitoring capabilities.

SRRP has published (1993) a number of reports on source reduction, use, recycling and alternatives of halogenated solvents. Relevant data on the type, use, and quantities of solvents were presented. Policy considerations include: planning and programs, multimedia dimensions, environmental and health considerations, streamlining regulations, removal of product and specification barriers, information technology transfer to small business, coordination with national and international jurisdictions, enhancing research and development, and increasing consumer information and education.

The U.S. government implemented an excise tax on ODS in 1991 that was intended to tax windfall profits to producers resulting from rising ODS prices. The tax is calculated by multiplying a tax rate specified for each type of ODS by the ozone-depletion factor, then multiplied by the pounds of each ODS sold by manufacturers or importers.

As example, the excise tax per pound of ODS will increase annually from $1.096 in 1991 to $4.28 in 1995 for CFC-113, compared with $0.137 and $0.535 for MCF.

The system is complicated by exemptions for ODSs used in feedstock where the chemical is consumed entirely or recovered for reuse. These taxes are paid annually and are expected to generate between $500 million and $1 billion per year.

The US-EPA is working with the Industry Cooperative for Ozone Layer Protection (ICOLP) to provide technical information and manuals on ODS alternatives including CFCs. In addition, the EPA requires labelling of products that contain, or were manufactured with Class I or Class II ODS and containers in which these substances have been purchased or stored (Section 611 of the Clean Air Act).

The final US-EPA ruling (FRL-4810-7) reported in December, 1993 sets the quantities apportioned to producers and importers of the controlled ODS solvents.

EPA compliance and control procedures include the requirement for an application for consumption documenting the users, name and quantity of substance, quantity transformed or destroyed and the efficiency of the destruction process.

HCFCs are subject to National Emissions Reduction Program that sets a **L**owest **A**chievable **E**mission **L**evel for HCFCs.

The Final Rule for the labling section in CAA published in February 1993 defines the types of products that must be labled and specifies the time-table for labling. The lable must identify the substance and that it "harms public health and environment by destroying ozone in the upper atmosphere" including CFCs and HCFCs.

5.3 Regulatory Activity of the Government of Canada:

Legislative action in Canada and elsewhere have been prompted by the **Montreal Protocol** which was signed in 1987. The signatories, including Canada, agreed to specific reductions in the production (and by implication, release) of ODS by certain dates. For example, governments agreed to eliminate production and consumption of CFCs by 1996, but with certain exemptions that would allow production or import for "essential uses" which are to be determined by an international technology and economic assessment panel.

For example, in November 1992, Canada and other parties to the Montreal Protocol agreed to new phase-out dates for CFCs, carbon tetrachloride, methyl chloroform, halons, HCFCs, HBFCs and methyl bromide. These nations further agreed to reduce production of HCFCs by 90% of the 1989 levels by 2015 and their total elimination of these chemicals by 2030.

To implement these agreements in the time frames specified, individual jurisdictions must enact legislation or Regulations under existing legislations. The government of Canada has

promulgated four regulations under the Canadian Environmental Protection Act which sets out command and control restrictions on the amount of CFC's that can be imported or manufactured in Canada.

Federal Regulation No. 1 restricts the manufacture and import of CFCs to the "actual aggregate weighed quantity" manufactured and imported during the preceding years starting in 1989. Imports can only come from countries that are participants of the Montreal Protocol.

The Canadian federal government is developing a new command and control regulation that is intended to:

- require a 75% reduction in the production, import and export of CFCs in 1994;
- require a 100% reduction on production, import and export of CFCs by 1996.

Federal Regulation No. 2 prohibits the manufacture of Halons (bromofluorocarbons) in Canada. Imports into Canada can only come from countries who are signatories to the Montreal Protocol.

Federal Regulation No. 3 prohibits the manufacture or importation of "10 kgs or less of any CFC contained in a pressurized container or any product in a pressurized container that contains 10 kgs or less of any CFC". After January 1, 1991, the sale of the aforementioned containers was also forbidden although some exemptions apply.

Ozone-Depleting Substances Regulation No. 4 (Carbon tetrachloride and Methyl chloroform), 1993 limits the use, manufacture, import or export of methyl chloroform and carbon tetrachloride. Allowable imports into Canada can only come from countries who are signatories to the Montreal Protocol.

Carbon Tetrachloride (CTC)

- From 1993 on, production and consumption are limited to 1989 levels.
- As of January 1, 1995, the use, manufacture, import or export of carbon tetrachloride is prohibited except for CTC recovered, recycled or reclaimed, or manufactured or imported before January 1, 1995 expept for: laboratory use, as a feedstock, in chlor-alkali plants and as analytical standard.
- Effective January 1, 2000, no person shall use CTC other than recovered, recycled, manufactured or imported before January 1, 2000 except as feedstock and analytical standard.
- After January 2000, use of CTC in chlor-alkali plants will no

longer be exempt.

Methyl Chloroform (MCF)

- Production and consumption is limited to 1989 levels as of 1993.

- The use, manufacture, import or export of methyl chloride is prohibited as of January 1, 2000 other than MCF that is recovered, recycled or reclaimed, or manufactured or imported before January 1, 2000 except for use as feedstock and as an analytical standard.

The federal regulations do not set a phase-out schedule for the use of CFCs and other ODS or their release into the environment. This means that CFCs already manufactured and in use in Canada can continue to be used and will ultimately be released to the atmosphere. HCFCs are not covered under any of these regulations. The federal regulations are currently under revision to adjust to the Montreal Protocol amendments.

Figure 6 illustrates the estimated quantities of CFC consumption between 1989 and 1994 under the existing federal regulation and what is expected between 1994 and 1996 if the proposed federal regulation is promulgated.

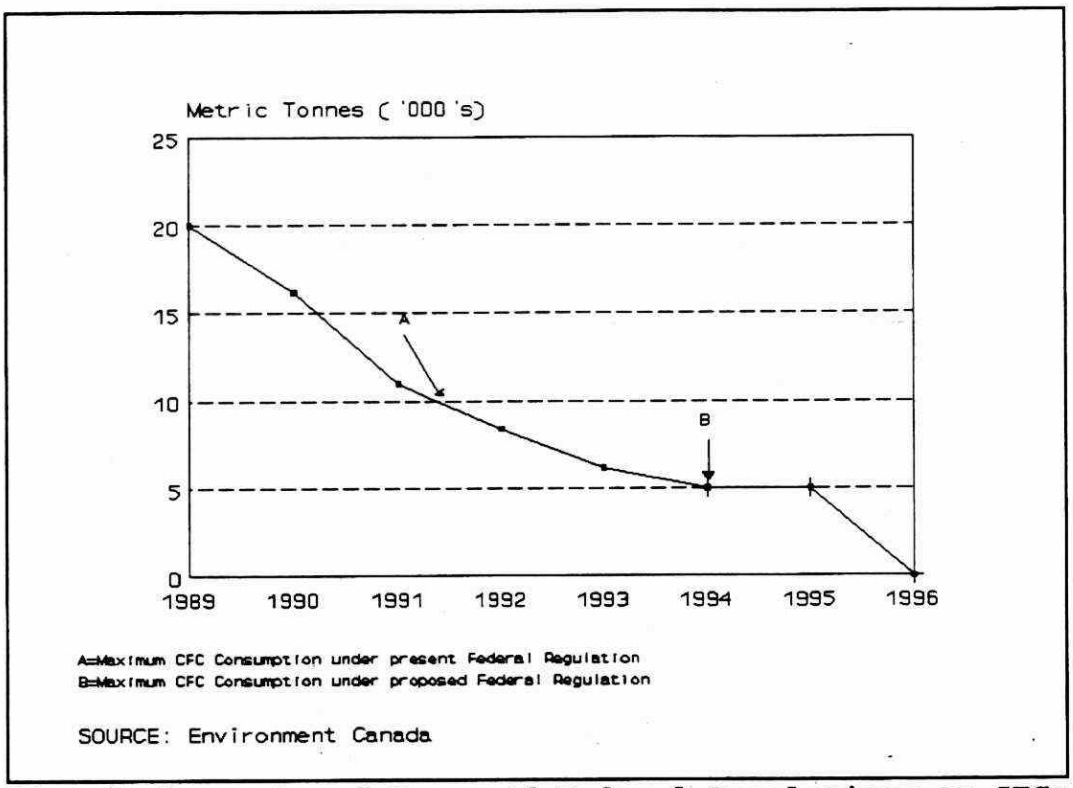


Fig. 6 Current and Proposed Federal Regulations on CFCs

5.4
Regulatory Activities in Other Provinces:

Alberta:

As of January 1, 1994, a general prohibition was put in-place on the manufacture, offer for sale, sale, or, except where permitted, release of ozone-depleting substances into the ambient air. The regulation applies to any thing that contains an ODS that is a cleaning solvent (MCF and CTC as of Jan. 1, 1996) for commercial use on electronic or electric equipment. Packaging or containers that contain or are manufactured by a process that uses an ODS are prohibited. Exemptions from the prohibition include ODS use for human and animal health care applications, and for laboratory use.

British Columbia:

British Columbia Regulation 53/93, part 5/Miscellaneous states that: effective July 1, 1994, a person must not use Class I substances to dissolve other substances for the purpose of cleaning. A person who contravenes the solvents section 26 of the regulation is liable to a fine not exceeding $200,000.
The regulation has been amended to extend the use of CFC-12 in sterilants to November, 1994.

Manitoba:

Use of ODS as Solvent:

Section 13 of the Manitoba regulation states that, after December 31, 1992, no person shall use a Class I substance to dissolve other substances for the purpose of commercially cleaning electrical or electronic equipment.

In Section 15, no person shall add to, mix or dissolve in a recovered ozone-depleting substance any foreign material, substance or waste that makes reclamation impractical.

Class I substances include specified CFCs, halons, CTC, MCF, and their isomers, while Class II lists specified HCFCs.
Despite of any provisions of the regulation, storage of recovered ODS is allowed if the condition or the quality of the substance is inadequate for recycling until destruction techniques for ODS are readily available.

The regulation does not take into consideration the phase-out dates of CFCs as set by the Montreal Protocol and the anticipated shortage of CFC supplies.

New Brunswick:

Among current provincial regulations, the New Brunswick regulation is the most specific one on the use of CFCs in solvents.

Section 32 of the Clean Environment Act, Regulation 92-119:

- Section 13: effective December 31, 1993, no person shall offer for sale, sell, lease, supply, purchase or use an ODS, except CTC and MCF, as a solvent.

- Section 14: subject to subsection 3, after December 31, 1994, no person shall offer for sale, sell, lease, supply, purchase or use CTC as a solvent.

- Section 15: subject to subsection 3, after December 31, 1999, no person shall offer for sale, sell, lease, supply, purchase or use MCF as a solvent.

Exemptions include the use of: CTC or MCF as a laboratory reagent, as a feed stock, ODS in health care and research and development. The Regulation prevails in case of a conflict with the Code-of Practice. Schedule A includes CFCs, CTC, and MCF, and Schedule B covers HCFCs.

Nova Scotia:

Control of cleaning solvents:

1. Subsections 2 and 3 apply to a cleaning solvent used on electrical or electronic equipment.

2. On or after July 1, 1991, no person shall import, manufacture, offer for sale or sell a cleaning solvent containing any CFC or MCF either alone or in a mixture in a pressurized container that has a capacity greater than 10 kilograms or in a non-pressurized container of any size unless that person files a registration report with the Administrator. The report may be amended.

3. A cleaning solvent is a designated product for the purpose of the ACT.

Québec:

Effective July 1, 1994, no person may use any solvent containing CFC or any product containing such solvent for a dry-cleaning operation.
Except for use in a laboratory or as feedstock, no person may use CTC after January 1, 1995, or MCF after January 1, 2000.

According to Quebec's regulation, effective June 1993, any person who uses the ozone-depleting substance released therefrom by using equipment designed to recover such substance.

Any person who sells or distributes CFCs, HCFCs or halons must submit reports to the Minister by March 31 of each year stating the main sector of activity and the name and quantity of the substance sold or distributed.

Schedule 1 includes four categories:
Category I : CFC-11, 12, 113, 114, 115, 500, 502 and 503;
Category II : Halons-1211, 1301 and 2402;
Category III : HCFC-22, 123, 124, 141-b and 142-b;
Category IV : MCF and CTC.

Saskatchewan:

The list of ODS in the Saskatchewan regulation includes specific CFCs, HCFCs, halons and their isomers.
The regulation states that, on and after January 1, 1995, no person shall manufacture, offer for sale or sell cleaning solvents for commercial use on electronic equipment, or the manufacture of products that contain ODS to which the Act applies.

Prince Edward Island:

Prince Edward Island is currently developing a regulation for the control of ODS. The "Draft" regulation identifies the conditions of sale, labelling and sales records.

"On or after January 1, 1995, no person shall make use of any product containing an ODS either alone or as a mixture for the purpose of:
b) dissolving another substance for cleaning purposes.
Also, the manufacture, sale or offer for sale of CTC and MCF are prohibited after January 1, 1995.

Storage of ODS waste in approved cylinders is permitted if the condition of waste does not allow for its recycling until approved destruction techniques are readily available.

Penalties for violations are covered under section 32 of the Act.

Ontario

The Ontario government has developed regulations to restrict the production and use of CFCs and other ozone-depleting substances in specific use categories. The first regulation is directed at CFCs used as refrigerants. A second regulation is intended to restrict the use of halons which are fire retardants.

A summary of provincial regulations on solvents is presented in Table 5.2.

Table 5.2: Provincial Regulations On **Solvents**

PROVINCE	Prohibitions	Exemptions
ALBERTA	- regulations apply to carbon tetrachloride (CTC) and methyl chloroform (MCF) as of Jan. 1 1996: ban of manufacture, offer for sale, sale of ODS solvents for cleaning commercial use on electronic or electrical equipment (Jan. 1, 1994)	- for laboratory use
BRITISH COLUMBIA	- effective Jan. 1, 1994, a person may not use a Class I substance as a component of a cleaning product - fines range up to $200,000	- considering amendments
MANITOBA	- after Dec. 31, 1992 no person shall use Class I substances to dissolve other substances for commercially cleaning of electrical or electronic equipment - no person shall add to or mix or dissolve in a recovered ODS any foreign material, substances or waste that makes reclamation impracticable	- it is not clear if the ban applies to cleaning electrical or electronic equipment only or for other purposes as well. - storage is allowed until destruction techniques are available
NEW BRUNSWICK	- Dec. 31, 1993: offer for sale, sell, lease, supply, purchase or use for as a solvent an ODS except for: CTC (Dec. 31, 1994), and MCF (Dec. 31, 1999) - Dec. 31, 1999 Ban HCFCs that has ODP > 0.02	- CTC and MCF used as a laboratory reagent for routine lab uses or converted to a different substance.
NOVA SCOTIA	- import, manufacture, offer for sale, sell cleaning solvent containing CFC/methyl chloroform in a PC with >10Kg or in a non-PC of any size	- if person files a registration report with the Administration
Prince Edward Island	- Jan. 1, 1995, manufacture or sale of solvents containing ODS, including CTC and MCF, for dissolving another substance for cleaning.	Storage in approved cylinders, until a destruction technology is available, is permitted if the condition of waste does not allow recycling.
QUÉBEC	- July 1, 1994: CFC solvent use in dry cleaning; - Jan. 1, 1995: use of carbon tetrachloride, CTC; - Jan. 1, 2000: use of methyl chloroform, MCF.	- use CTC or MCF in laboratories, chemical synthesis, or the production of a product in which the chemical nature is changed.
SASKATCHEWAN	- Jan. 1, 1994, manufacture, offer for sale and sell of cleaning solvents for commercial use on electronic equipment	

5.5 Potential Responses to Regulatory Requirements

Supplier and manufacturing firms are currently researching and developing new substitutes and chemicals as well as alternative cleaning techniques for ODS solvents.

There exist many different types of uses, users and specifications and data on the numbers of users in each use section are not available. Furthermore, there are many different potential technical options that solvent users could adopt to replace ODS solvents. Consequently, it has not been possible to predict specific users responses at this time.

Furthermore, in a few instances, customers of parts and components that involve solvent cleaning have specified that suppliers warrant that no CFCs be used in the production of the products they buy. These conditions could easily be applied to other ODS solvents. In this way, market forces are helping to achieve the objectives set out in the Montreal Accord.

REFERENCES

Abt Associates of Canada. Project Report: An Assessment of the Economic Impacts of a Ban on the Use of Chlorofluorocarbons in Solvent Applications. Environment Canada, 1990.

Bailey, Jennifer, Commercial Chemicals Branch. Draft ODS Alternatives and Suppliers List. Environment Canada, Aug. 1993.

Environment Canada. Methyl Chloroform: The Impact of Its Elimination as an Industrial Solvent. Environment Canada, 1991.

Polhamus, Robert L., Branson Ultrasonics Corporation, Danbury, carbon tetrachloride. Process & Cost Comparison of Solvent & Alternative Cleaning Systems. In the Proceedings of the 1992 International CFC and Halon Alternatives Conference, Stratospheric Ozone Protection for the 90's, Washington, D.C., September 1992.

Schleckser, Jim, Ney Ultrasonics Inc. Non-CFC Precision Cleaning Alternatives - The Choices and the Costs. In the Proceedings of the 1993 International CFC and Halon Alternatives Conference, Stratospheric Ozone Protection for the 90's, Washington, D.C. Oct. 20-22, 1993.

U.S. EPA/ICOLP. Conservation and Recycling Practices for CFC-113 and Methyl Chloroform. EPA/400/1-91/017, 1991.

U.S. EPA/ICOLP. Eliminating CFC-113 And Methyl Chloroform in Aircraft Maintenance Procedures. EPA-430-B-93-006, 1993.

U.S. EPA/ICOLP. Eliminating CFC-113 And Methyl Chloroform in Precision Cleaning Operations. EPA/400/1-91/018, 1991.

U.S. EPA/ICOLP. Alternatives for CFC-113 And Methyl Chloroform in Metal Cleaning. EPA/400/1-91/019, 1991.

U.S. EPA/ICOLP. Aqueous And Semi-Aqueous Alternatives For CFC-113 And Methyl Chloroform Cleaning of Printed Circuit Board Assemblies. EPA/400/1-91/016, 1991.

U.S. EPA/ICOLP. No-Clean Soldering To Eliminate CFC-113 and Methyl Chloroform Cleaning of Printed Circuit Board Assemblies. EPA-430-B-93-005, 1993.

U.S. EPA. Protection of Stratospheric Ozone; Proposed Rule. Federal Register Part II, 40 CFR Part 82, May 12, 1993.

U.S. EPA. Excerpts from: Draft Guide To Clean Technology - Alternatives To Chlorinated Solvents For Cleaning and Degreasing, July 1992, In The Great Lakes Pollution Prevention Centre Presents Water-Based Alternatives to Solvent Cleaning, Feb. 1993

UNEP IE/PAC. Protecting the Ozone Layer, Volume 5, Aerosols, Sterilants, Carbon Tetrachloride and Miscellaneous Uses. France 1992.

UNEP IE/PAC. Protecting the Ozone Layer, Volume 2, Solvents, Coatings and Adhesives. France, 1992.

UNEP. Montreal Protocol 1991 Assessment, Report of the Solvents, Coatings and Adhesives Technical Options Committee. 1991.

UNEP. Montreal Protocol, 1991 Assessment, Report of the Aerosol Products, Sterilants, Miscellaneous Uses and Carbon Tetrachloride Technical Options Committee. 1991.

Wolf, Kathy. Analysis of Alternatives to Ozone-Depleting Solvents in Cleaning Applications. Pollution Prevention Review, Volume 2, Number 2, Spring 1992, pg 133-151.

APPENDIX A

A.1 Methyl Chloroform, MCF, - Uses and Alternatives:

Methyl chloroform			
Ozone Depleting Substance and Properties	Uses	Alternative	Comments
Methyl chloroform ODP = 0.1 1,1,1-Trichloroethane CH_3CCl_3 M.W.: 133.4 B.P.: 74°C M.P.: 30.4°C D: 1.34 g/cm^2	•Electronics cleaning:to remove flux residues on circuit boards	•Aqueous and semi-aqueous cleaners: e.g., alcohol-based, petroleum-based or terpene	•Wastewater treatment required. •Increased water and energy use •Unsuitable for surface mounted boards •New equipment required •Lower costs •Reduced waste management costs •Increased floor space needed •Organic component may be a VOC •U.S. industry studies indicated that 80% could switch to semi-aqueous cleaning

Methyl chloroform			
Ozone Depleting Substance and Properties	Uses	Alternative	Comments
		•Organic solvents: e.g., Alcohols, Ketones & Glycol Ethers	•Short atmospheric lifetimes •Photochemically active •Some are toxic •Flammable •Emission control equipment available •Polarity good for cleaning fluxes •Isopropanol & acetone close alternatives •Not very effective with non-polar greases & waxes •Often used for wipe cleaning •Some have vapour pressures that are too high to be used in standard process equipment •Generate no wastewater when used undiluted

Methyl chloroform			
Ozone Depleting Substance and Properties	Uses	Alternative	Comments
		•Chlorinated solvents: Trichloroethylene (TCE), Perchloroethylene (PCE), Methylene chloride (METH)	•These solvents do not fill any special cleaning niche for the electronics industry •Short atmospheric lifetimes •Toxicity concerns (TCE & PCE) •PCE and TCE are VOCs •Needs emission control equipment •Can be used in conventional vapour degreasing equipment
		•Hydrocarbons: e.g., napthas, mineral spirits, kerosene, toluene and xylene	•Stoddard solvent is widely accepted for cold cleaning •Flammability concerns •VOC control may be required •Occupational health concerns •Good cleaning ability
		•Terpene (d-limonene)	•Photochemically active •Flammable

Methyl chloroform			
Ozone Depleting Substance and Properties	Uses	Alternative	Comments
		•Supercritical fluids	•Flexible, properties can be altered •Rapid cleaning time •Lower operating costs e.g., utilities •High capital costs because of need to operate at high temperatures •Substrate may be adversely effected
		•Perfluorocarbons	•Global warming concerns •May be the only alternative for certain computer components •Relatively expensive •Low toxicity •Poor solvents for hydrocarbon greases •Good solvents for halogenated polymers •Nonflammable •Can be used with alcohols for cleaning of rosin from circuit boards

Methyl chloroform			
Ozone Depleting Substance and Properties	Uses	Alternative	Comments
		•Plasma cleaning e.g., oxygen, argon, helium, silicon tetrafluoride and air	•Process gases are cheap •Nontoxic and non-caustic •No disposal procedures required •Low operating costs •High initial capital costs •Uneven cleaning •Poor solvents for hydrocarbon greases •Good solvents for halogenated polymers
		•UV/ozone cleaning	•Experimental •Requires worker protection from UV and ozone exposure
		•Ultrasonic cleaning	•Sound waves create a scrubbing action •Good for small parts •Not good on nested parts or difficult holes •Usually slows down production •Provides good mechanical cleaning

Methyl chloroform			
Ozone Depleting Substance and Properties	Uses	Alternative	Comments
		●Laser Cleaning	●System can be tuned to remove a given contaminant ●No solid waste generation ●Experimental ●Dependant on the differences in contaminants and substrate
		●Carbon Dioxide	●Low cost and easy to operate ●Minimal waste ●Limited to particulate removal ●Substrate damage with high pressures ●Static sensitive devices can be damaged
		●No-clean technologies	●Examples of no-clean alternatives: - Do not de-flux - No Flux Soldering - Low Solids Flux ●As much as 70% could switch to no clean processes (US-EPA) ●Risks - worker safety ●Less waste is generated

Methyl chloroform			
Ozone Depleting Substance and Properties	Uses	Alternative	Comments
		●HCFC-141b ●HCFC-141b blends ●HCFC-31/122 ●HCFC-123	●HCFCs are not widely available ●Similar cleaning ability to CFC-113 ●Similar physical properties ●HCFC-141b and HCFC-123 require equipment changes ●High ODP ●Possible toxicity concerns ●Produces no wastewater
	Metal cleaning: removing cutting oils and metal filings	●Aqueous and semi-aqueous cleaners: e.g., alcohol-based, petroleum-based or terpene	●Mainly used for metals cleaning ●A wide variety of alternative chemicals available ●Wastewater treatment required ●Increased water and energy use ●New equipment required ●Lower costs ●Reduced waste management costs ●Increased floor space needs ●Ferrous parts may rust easily ●Worker exposure to chemicals ●Improved cleanliness ●Good for organic/particulate removal ●Long established technology ●Organic component may be a VOC

Methyl chloroform			
Ozone Depleting Substance and Properties	Uses	Alternative	Comments
		•Water	•Good removal of ionic soils •Water pretreatment not needed •Need for water demineralization •Increased water and energy use •Rusting of ferrous parts
		•Organic solvents: e.g., Alcohols, Ketones & Glycol Ethers	•Photochemically active •Short atmospheric lifetimes •Some are toxic •Flammable •Emission control equipment available •Polarity good for cleaning fluxes •Isopropanol & acetone close alternatives •Not very effective with non-polar greases & waxes •Often used for wipe cleaning •Some have vapour pressures that are too high to be used in standard process equipment

Methyl chloroform			
Ozone Depleting Substance and Properties	Uses	Alternative	Comments
		•Chlorinated solvents: Trichloroethylene (TCE), Perchloroethylene (PCE), Methylene chloride (METH)	•Short atmospheric lifetimes •Toxicity concerns (TCE & PCE) •PCE and TCE are VOCs •Needs emission control equipment •Can be used in conventional vapour degreasing equipment
		•Hydrocarbons: e.g., napthas, mineral spirits, kerosene, toluene and xylene	•Stoddard solvent widely accepted for cold cleaning •Flammability concerns •VOC control may be required •Occupational health concerns •Good cleaning ability
		•Supercritical carbon dioxide	•Good for oil removal from crevices and porous parts •Technology in research phase •High initial costs •Limited to cleaning small parts

Methyl chloroform			
Ozone Depleting Substance and Properties	Uses	Alternative	Comments
		●Plasma cleaning e.g., oxygen, argon, helium, silicon tetrafluoride and air	●Process gases are cheap ●Nontoxic and non-caustic ●No disposal procedures required ●Low operating costs ●High initial capital costs ●Uneven cleaning ●Poor solvents for hydrocarbon greases ●Good solvents for halogenated polymers
		●Abrasives/ Mechanical Removal	●Wide range available ●Starch & carbon dioxide pellet blasting ●Need for dust or dirt control ●Potential damage to parts
		●UV/ozone cleaning	●Experimental ●Requires worker protection from UV and ozone exposure

Methyl chloroform			
Ozone Depleting Substance and Properties	Uses	Alternative	Comments
		•Ultrasonic cleaning	•Sound waves create a scrubbing action •Good for small parts •Not good on nested parts or difficult holes •Usually slows down production •Provides good mechanical cleaning
		•No-clean technologies	•Few no clean alternatives are available due to heavy oil use
		•HCFC-141b, diluted HCFC-141b blends, HCFC-31/122, HCFC-123	•HCFCs are not widely available •Similar cleaning ability to CFC-113 •Similar physical properties •HCFC-141b and HCFC-123 may involve equipment changes •High ODP •Possible toxicity concerns •Produces no wastewater

Methyl chloroform			
Ozone Depleting Substance and Properties	Uses	Alternative	Comments
	Precision cleaning: technical constraints expected in cleaning alternatives	•Aqueous and semi-aqueous cleaners: e.g., alcohol-based, petroleum-based or terpene	•Potential to service up to 65% of the precision cleaning market •Wide variety of chemicals for use •Wastewater treatment required •Increased water and energy use •New equipment required •Reduced solvent costs •Reduced waste management costs •Increased floor space needs •Ferrous parts may rust easily •Worker exposure to chemicals •Increased cleaning efficiency •Good for organic/particulate removal. •Long established technology •Organic component may be a VOC

Methyl chloroform			
Ozone Depleting Substance and Properties	Uses	Alternative	Comments
		●Perfluorocarbons	●Global-warming concerns ●May be the only alternative for certain computer components ●Relatively expensive ●Low toxicity ●Poor solvents for hydrocarbon greases ●Good solvents for halogenated polymers ●Nonflammable
		●Plasma cleaning e.g., oxygen, argon, helium, silicon tetrafluoride and air	●Process gases are cheap ●Nontoxic and non-caustic ●No disposal procedures required ●Low operating costs ●High initial capital costs ●Uneven cleaning ●Poor solvents for hydrocarbon greases ●Good solvents for halogenated polymers

Methyl chloroform			
Ozone Depleting Substance and Properties	Uses	Alternative	Comments
		●Supercritical fluids	●Flexible, properties can be altered ●Rapid cleaning time ●Lower operating costs ●High capital costs because of need to operate at high temperatures ●Substrate may be adversely effected
		●Pressurized gas cleaning	●Possible gases: e.g., air, rare gases, carbon dioxide, chlorodifluoromethane (HCFC-22) and nitrogen ●Low viscosity ●Low toxicity ●High diffusion ●Nonflammable ●Low capital cost ●Low density ●High pressure may cause rupturing of seal ●Often not effective for microscopic particles

Methyl chloroform			
Ozone Depleting Substance and Properties	Uses	Alternative	Comments
		•HCFC-224ca, HCFC-225cb, HCFC-123, HCFC-141b, alcohol blends	•HCFCs may not be widely available •Similar cleaning ability to CFC-113 •Similar physical properties •HCFC-141b and HCFC-123 require equipment changes •High ODP •Possible toxicity concerns •HCFC-225 is a straight drop in - only minor modifications required •Produces no wastewater
	Adhesives: solvent is evaporated leaving behind the binder.	•Water-based adhesives	• Slower drying, weaker adhesive bond may require increased use of adhesive • Reduced solvent content
		•Alternative technologies such as hot-melt system	•Limited to non-heat sensitive substrate, bond brittle at low temperatures •Short set-time, strong bonding, cost effective
		•Radiation curing	•High cost, need for UV light or electron beam source

Methyl chloroform			
Ozone Depleting Substance and Properties	Uses	Alternative	Comments
		•High-solids adhesives	•May require in-line heater •Increased spray nozzle wear •Can be used with existing equipment
		•Powder adhesives	• Easy to apply, overspray can be collected and reused •Limited to non-heat sensitive materials
		•Reactive liquids	•Need for exact amounts and mixing of ingredients •Provides good bonding
		•Use of high efficiency spray equipment	•Need for new equipment. May cause hazards (high pressure sprays, sparking) •Less adhesives waste •Cost-effective
		•Petroleum distillates	•Increased VOC emissions •Flammability •Reduced costs
		•Chlorinated solvents	•Increases VOC emissions •Less expensive

Methyl chloroform			
Ozone Depleting Substance and Properties	Uses	Alternative	Comments
		•Use of flow coater, dip or brush	•High transfer efficiency •Reduced waste •Limited to flat objects
		•Mechanical fasteners or welds	•Limited application potential. •Increased product weight. •Eliminates use of adhesive.
	Coatings: MCF is used as a reaction medium	•Water-based formulations	•Some formulations contain standard solvents for ease of application •Good wetting properties •High surface tension •Aprox. 55 % of flexographic inks and 15 % of gravure inks in the U.S. in 1987 were water based
		•High-solid coatings	•Contain less solvent and more resin •Many application methods available •Finish is superior to solvent-based coatings
		•Powder coatings	•Resin is contained in powder form - no solvent •Applied using fluidized beds, electrostatic spray and fluidized beds

Methyl chloroform			
Ozone Depleting Substance and Properties	Uses	Alternative	Comments
	Dry Cleaning	•Perchloroethylene (PCE)	•Common dry cleaning solvent •contributes to ground-level ozone
		•Petroleum solvents: e.g., Stoddard Solvent	•Cleaning ability similar to PCE. •Requires explosion proof equipment •solvent is photochemically reactive •Fire hazards
		•HCFC-225	•HCFCs are not widely available •High ODP
	Pressurized Solvents	•Product reformulation	•Increased flammability •Performance level •Replacement of propellant may require increased solvent content to maintain viscosity
		•Non-aerosol packaging	•Eliminates use of solvent as propellant •Product can be easily recovered if sprayer jams or breaks •Product may not perform as well as aerosol product •Greater potential for product contamination or spillage.

Methyl chloroform			
Ozone Depleting Substance and Properties	Uses	Alternative	Comments
O.D.P.: Ozone Depleting Potential (1.0 for CFC-11) M.W.: molecular weight B.P.: boiling point M.P.: melting point D: density			

A.2 Trichlorotrifluoroethane, CFC-113, - Uses and Alternatives:

CFC-113			
Ozone Depleting Substance and Properties	Uses	Alternative	Comments
CFC-113 ODP = 0.8 Trichlorotri-fluoromethane $C_2F_3Cl_3$ M.W.: 187.4 B.P.: 48°C M.P.: -36.4°C D: 1.56 g/cm^2	Electronics cleaning: to remove flux residue on circuit boards •CFC-113 is mainly used	•Aqueous and semi-aqueous cleaners: e.g., alcohol-based, petroleum-based or terpene	•Wastewater treatment required. •Increased water and energy use depending on bath temperature •Not suitable for surface mounted boards •New equipment required •Reduced solvent costs •Reduced waste management costs •Increased floor space needs •U.S studies indicated that 80% of users could switch to semi-aqueous cleaning •Organic component may be a VOC

CFC-113			
Ozone Depleting Substance and Properties	Uses	Alternative	Comments
		•Organic solvents: e.g., Alcohols, Ketones & Glycol Ethers	•Short atmospheric lifetimes •Photochemically active •Some are toxic •Flammable •Emission control equipment available •Polarity good for cleaning fluxes •Not very effective with non-polar greases and waxes •Isopropanol and acetone close alternatives •Often used for wipe-cleaning •Some have vapour pressures that are too high to be used in standard process equipment •Generate no wastewater if undiluted
		•Chlorinated solvents: trichloro-ethylene (TCE), perchloro-ethylene (PCE), methylene chloride (METH)	•Short atmospheric lifetimes •Toxicity concerns (TCE & PCE) •PCE and TCE are VOCs •Emission control equipment is available •Can be used in conventional vapour degreasing equipment

CFC-113			
Ozone Depleting Substance and Properties	Uses	Alternative	Comments
		•Hydrocarbons: e.g., napthas, mineral spirits, kerosene, toluene and xylene	•Stoddard solvent widely accepted in cold cleaning applications •Flammability concerns •VOC control may be required •low occupational exposure limits for some substances •Good cleaning ability for a wide range of soils
		Terpene (d-limonene)	•Flammable •Photochemically active
		•Super-critical fluids	•Properties can be altered to suit •Rapid cleaning time •Lower operating costs •High initial capital costs because of need to operate at high temperatures •Substrate may be adversely effected

CFC-113			
Ozone Depleting Substance and Properties	Uses	Alternative	Comments
		•Perfluoro-carbons	•Global-warming concerns •Unique for certain computer components •Relatively expensive •Low toxicity •Nonflammable •Poor solvents for hydrocarbon greases •Good solvents for halogenated polymers •Can be used with alcohols for cleaning rosin from printed circuits
		•Plasma cleaning e.g., oxygen, argon, helium, silicon tetrafluoride and air	•Low cost of process gases •Non-toxic and non-caustic •No disposal procedures required •Low operating costs •High initial capital costs •Uneven cleaning •Poor solvents for hydrocarbon greases •Good solvents for halogenated polymers
		•UV/ozone cleaning	• Experimental • Requires worker protection from UV and ozone exposure

CFC-113			
Ozone Depleting Substance and Properties	Uses	Alternative	Comments
		•Ultrasonic cleaning	•Sound waves create a scrubbing action •Good for small parts •Not good on nested parts or difficult holes •Usually slows down production •Provides good mechanical cleaning
		•Laser Cleaning	•System can be tuned to remove a given contaminant •No solid waste generation •Experimental •Dependant on the differences between contaminant and substrate properties
		•Carbon Dioxide Snow	•Low-cost and easy to operate •Minimal waste •Limited to particulate removal •Substrate damage with high pressures •Static sensitive devices can be damaged

CFC-113			
Ozone Depleting Substance and Properties	Uses	Alternative	Comments
		•No-clean technologies	•Examples of no-clean alternatives: - Do not de-flux - No Flux Soldering - Low Solids Flux •As much as 70% of users could switch to no clean processes •Risks to worker safety •Less waste is generated
		•HCFC-141b •diluted HCFC-141b blends, HCFC-31/122, HCFC-123	•HCFCs are not widely available •Similar cleaning ability to CFC-113 •Similar physical properties •HCFC-141b and HCFC-123 may require equipment changes •High ODP •Possible toxicity concerns •Produces no wastewater

CFC-113			
Ozone Depleting Substance and Properties	Uses	Alternative	Comments
	Precision Cleaning: • mainly CFC-113 •Used in many industrial cleaning operations including cleaning of pacemakers and special computer parts	•Aqueous and semi-aqueous cleaners: e.g., alcohol-based, petroleum-based or terpene/ surfactant	•Has the potential to service approx. 65% of the precision cleaning market •A wide variety of chemicals available for use •Wastewater treatment required •Increased water and energy use •New equipment required •Elimination of high solvent costs •Reduced waste management costs •Increased floor space needs •Ferrous parts may rust easily •Worker exposure to chemicals •Increased cleaning efficiency •Good for organic soil/particulate removal •Long established technology •Organic component may be a VOC

CFC-113			
Ozone Depleting Substance and Properties	Uses	Alternative	Comments
		•Organic solvents: e.g., Alcohols, Ketones & Glycol Ethers	•Short atmospheric lifetimes •Photochemically reactive •Some are toxic •Flammable •Emission control equipment available •Polarity good for cleaning fluxes •Isopropanol & acetone close alternatives •Less effective with non-polar greases •Often used for wipe cleaning •Some have vapour pressures that are too high to be used in standard process equipment •Generate no wastewater when used undiluted
		•Chlorinated solvents: trichloroethylene (TCE), perchloro-ethylene (PCE), methylene chloride (METH)	•Short atmospheric lifetimes •Toxicity concerns (TCE & PCE) •PCE and TCE are VOCs •Emission control equipment is available •Can be used in conventional vapour degreasing equipment
		•UV/ozone	•Experimental •Requires protection from UV and ozone

CFC-113			
Ozone Depleting Substance and Properties	Uses	Alternative	Comments
		•Perfluoro-carbons (C	•Global-warming concerns •Relatively expensive •Low toxicity •Poor solvents for hydrocarbon greases •Good solvents for halogenated polymers •Nonflammable
		•Plasma Cleaning e.g., oxygen, argon, helium, silicon tetrafluoride and air	•Process gases are cheap •Non-toxic and non-caustic •No disposal procedures required •Low operating costs •High initial capital costs •Uneven cleaning •Poor solvents for hydrocarbon greases •Good solvents for halogenated polymers
		•Supercritical fluids	•Flexible, properties can be altered •Rapid cleaning time •Lower operating costs •High initial capital costs because of need to operate at high temperatures •Substrate may be adversely effected

CFC-113			
Ozone Depleting Substance and Properties	Uses	Alternative	Comments
		•Pressurized gas cleaning	•Possible gases: air, rare gases, carbon dioxide, chlorodifluoromethane (HCFC-22) and nitrogen •Low viscosity •Low toxicity •High diffusion •Non-flammable •Low capital cost •Low density •High pressure may cause rupturing of seal •Often not effective for microscopic particles
		•HCFC-224ca, HCFC-225cb, HCFC-123,HCFC-141b, alcohol blends	•HCFCs are not widely available •Similar cleaning ability to CFC-113 •HCFC-141b and HCFC-123 would involve equipment changes •HCFC-225ca and 225cb have potential to replace CFC-113 in certain precision cleaning applications •HCFC-225 can be used as a drop-in with some modification •High ODP •Possible toxicity concerns •Produces no wastewater

CFC-113			
Ozone Depleting Substance and Properties	Uses	Alternative	Comments
	Metal Cleaning: removing cutting oils and metal filings	•Aqueous and semi-aqueous cleaners: e.g., alcohol-based, petroleum-based or terpene	•Mainly used for metals cleaning •A wide variety of chemicals are available •Wastewater treatment required •Increased water and energy use •New equipment required •Reduced solvent costs •Reduced waste management costs •Increased floor space needs •Ferrous parts may rust easily •Worker exposure to chemicals •Higher efficiency than solvent cleaning •Good for organic soil/particulate removal. •Long established technology •Organic component may be a VOC
		•Water	•Good removal of ionic soils •Pretreatment of water may not be necessary •Need for water demineralization system •Increased water and energy use •Potential rusting of ferrous parts

CFC-113			
Ozone Depleting Substance and Properties	Uses	Alternative	Comments
		•Organic solvents: e.g., Alcohols, Ketones & Glycol Ethers	•Short atmospheric lifetimes •Photochemically active •Some are toxic •Flammable •Emission control equipment available •Polarity good for cleaning fluxes •Not very effective with non-polar greases and waxes •Isopropanol & acetone close alternatives •Often used for wipe cleaning •Some have vapour pressures that are too high to be used in standard process equipment •Generate no wastewater when used undiluted
		•Chlorinated solvents: trichloroethylene (TCE), perchloro-ethylene (PCE), methylene chloride (METH)	•Short atmospheric lifetimes •Toxicity concerns (TCE & PCE) •PCE and TCE are VOCs •Emission control equipment is available •Can be used in conventional vapour degreasing equipment

CFC-113			
Ozone Depleting Substance and Properties	Uses	Alternative	Comments
		•Hydrocarbons: e.g., napthas, mineral spirits, kerosene, toluene and xylene	•Stoddard solvent widely accepted in cold cleaning applications •Flammability concerns •VOC control may be required •low occupational exposure limits for some substances •Good cleaning ability for a wide range of soils
		•Super-critical carbon dioxide	•Highly-effective at removing oil from crevices and porous parts •Technology in research phase •High initial cost limited to cleaning small objects
		•Plasma cleaning e.g., oxygen, argon, helium, silicon tetrafluoride and air	•Process gases are cheap •Non-toxic and non-caustic •No disposal procedures required •Low operating costs •High initial capital costs •Uneven cleaning •Poor solvents for hydrocarbon greases •Good solvents for halogenated polymers

CFC-113			
Ozone Depleting Substance and Properties	Uses	Alternative	Comments
		•Abrasives	•Wide range available •Starch & carbon dioxide pellet blasting show promise for general purpose •Need for dust or dirt control •Potential damage to parts
		•UV/ozone cleaning	•Experimental •Requires protection from UV and ozone
		•Ultrasonic cleaning	•Sound waves create a scrubbing action •Good for small parts •Not good on nested parts or difficult holes •Usually slows down production •Provides good mechanical cleaning
		•No-clean technologies	•Few no clean alternatives are available due to heavy oil use

CFC-113			
Ozone Depleting Substance and Properties	Uses	Alternative	Comments
		•HCFC-141b, diluted HCFC-141b blends, HCFC-31/122, HCFC-123	•HCFCs are not widely available •Similar cleaning ability to CFC-113 •Similar physical properties •HCFC-141b and HCFC-123 may involve equipment changes •High ODP •Possible toxicity concerns •Produces no wastewater
	Dry Cleaning	•Perchloro-ethylene (PCE)	•Most common dry cleaning solvent •contributes to ground-level ozone
		•Petroleum solvents: e.g., Stoddard Solvent	•Cleaning ability similar to PCE •Risk from explosion •solvent is photochemically reactive •Flammable
		•HCFC-225	•HCFCs are not widely available •High ODP

CFC-113			
Ozone Depleting Substance and Properties	Uses	Alternative	Comments
O.D.P.: Ozone Depleting Potential (1.0 for CFC-11) M.W.: molecular weight B.P.: boiling point M.P.: melting point D: density			

A.3 Carbon Tetrachloride, CTC, Uses and Alternatives:

<table>
<tr><td colspan="4">Carbon tetrachloride</td></tr>
<tr><td>Ozone Depleting Substance and ODP</td><td>Uses</td><td>Alternative</td><td>Comments</td></tr>
<tr><td rowspan="2">Carbon Tetrachloride
ODP = 1.1

Tetrachloromethane
Perchloromethane
CCl_4

M.W.: 153.82
B.P.: 76.5°C
M.P.: -23°C
D: 1.59 g/cm^2</td><td>●Feedstock for CFC-11,12</td><td>●CFC 11,12 no longer produced in Canada
●Carbon tetrachloride still exported</td><td rowspan="2">●Some carbon tetrachloride is used to produce CFC-12 for sterilization purposes</td></tr>
<tr><td>Solvent Uses:
●Inert solvent in chlorination reactions
●Production of chlorine
●Feedstock for other chlorinated hydrocarbons</td><td></td></tr>
<tr><td colspan="4">O.D.P.: Ozone Depleting Potential (1.0 for CFC-11)
M.W.: molecular weight
B.P.: boiling point
M.P.: melting point
D: density</td></tr>
</table>

A.4 Hydrochlorofluorocarbons, HCFCs, - Uses and Alternatives:

Ozone Depleting Substance and ODP	Uses	Alternative	Comments
HCFC-123 ODP = 0.02 Dichloro-trifluoro-ethane $C_2HCl_2F_3$ HCFC-141b ODP = 0.11 Dichloro-fluoro-ethane $C_2H_3Cl_2F$ HCFC-225ca ODP = -0.05 Dichloro-pentafloro-propane $C_3Cl_2F_5$ B.P.: 51.1 °C HCFC-225cb Dichloro-pentafluoro-propane ODP = -0.05 $C_3Cl_2F_5$ B.P.: 56.1 °C	Electronics Cleaning (HCFC-141b and HCFC-141b blends, HCFC-31/122, HCFC-123)	• Terpene (d-limonene)	• Similar physical properties and cleaning ability to CFC-113 and Methyl chloroform • Possible toxicology concerns • DuPont is not recommending HCFCs for degreasing • HCFCs are used in enclosed systems, and not in vapour degreasers • Short-term solution • HCFCs will not be widely available • HCFC-141b and HCFC-123 would involve equipment changes • HCFC-123 use would require major retrofitting of vapour degreasing equipment or replacement • Allied-Signal has indicated that HCFC-141b will not be available as a cleaning solvent • HCFC-225ca and 225cb have potential to replace CFC-113 in precision cleaning • DuPont will not offer HCFC-123 for cleaning operations
	(HCFC-224ca, HCFC-225cb, HCFC-123, HCFC141b)	• Plasma cleaning	

O.D.P.: Ozone Depleting Potential (1.0 for CFC-11)
M.W.: molecular weight, B.P.: boiling point
M.P.: melting point, D: Density

TD
196
.S54
R44
1994

Regulating ozone-depleting
substances in Ontario's solvents
[illegible]

72992